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ANNEXES 1 to 10

ANNEXES

to the

Commission Regulation (EU) .../...

amending Regulation (EU) 2017/2400 as regards the determination of the CO2 emissions and fuel consumption of medium and heavy lorries and heavy buses and to cover vehicles running on hydrogen and other new technologies and amending Regulation (EU) 582/2011 as regards the applicable rules on the determination of CO2 emissions and fuel consumption in order to obtain an extension to an EU type-approval

ANNEX I

In point 1.1. of Annex I, table 1 is replaced by the following:

'Table 1

Vehicle groups for heavy lorries

Description of elements relevant to the classification in vehicle groups			Vehicle group	Allocation of mission profile and vehicle configuration						
Axle configuration	Chassis configuration	Technically permissible maximum laden mass (tons)		Long haul	Long haul EMS(*)	Regional delivery	Regional delivery EMS(*)	Urban delivery	Municipal utility	Construction
4x2	Rigid lorry (or tractor)(**)	> 7,4 –7,5	1s			R		R		
	Rigid lorry (or tractor)(**)	> 7,5 – 10	1			R		R		
	Rigid lorry (or tractor)(**)	> 10 – 12	2	R+ T1		R		R		
	Rigid lorry (or tractor)(**)	> 12 – 16	3			R		R		
	Rigid lorry	> 16	4	R+ T2		R		R	R	R
	Tractor	> 16	5	T+ ST	T+ST+T 2	T+ST	T+ST+T 2	T+ST		T+ST
4x4	Rigid lorry	> 7,5 – 16	(6)							
	Rigid lorry	> 16	(7)							
	Tractor	> 16	(8)							
6x2	Rigid lorry	all weights	9	R+ T2	R+D+ST	R	R+D+ST		R	R
	Tractor	all weights	10	T+ ST	T+ST+T 2	T+ST	T+ST+T 2			T+ST
6x4	Rigid lorry	all weights	11	R+ T2	R+D+ST	R	R+D+ST		R	R
	Tractor	all weights	12	T+ ST	T+ST+T 2	T+ST	T+ST+T 2			T+ST
6x6	Rigid lorry	all weights	(13)							
	Tractor	all weights	(14)							
8x2	Rigid lorry	all weights	(15)							
8x4	Rigid lorry	all weights	16	R+ T2	R+D+ST	R	R+D+ST			R
8x6 8x8	Rigid lorry	all weights	(17)							

8x2 8x4 8x6 8x8	Tractor	all weights	(18)	
5 axles, all configurations	Rigid lorry or tractor	all weights	(19)	

(*) EMS - European Modular System

(**) In these vehicle classes tractors are treated as rigid lorries but with specific curb weight of tractor

T = Tractor

R = Rigid lorry & standard body

T1, T2 = standard trailers

ST = standard semitrailer

D = standard dolly

ANNEX II

Annex III is amended as follows:

(1) in point 2, the following points are added:

‘(38) ‘dynamic charging technology’ means a technology that enables the vehicle to be connected to an external electrical power supply while in motion, providing direct power to the vehicle's propulsion and/or auxiliary systems and/or charging the batteries;

(39) ‘overhead pantograph’ means dynamic charging technology for connection and power supply with overhead contact line infrastructure on roads as regulated by standard;

(40) ‘overhead trolley’ means dynamic charging technology with current collector poles for connection with overhead contact line infrastructure;

(41) ‘ground rail’ means dynamic charging technology that conductively transfers the electrical energy to the vehicle through rails embedded in or on top of the road surface;

(42) ‘wireless’ means dynamic charging technology that inductively transfers the electrical energy to the vehicle through devices embedded in or on top of the road surface providing magnetic fields;

(43) ‘compressed gaseous hydrogen’ means a hydrogen storage technology which stores hydrogen in gaseous form at 35 MPa, 15°C or 70 MPa, 15°C;

(44) ‘liquid hydrogen’ means a hydrogen storage technology which stores hydrogen in liquid form;

(45) ‘cryo-compressed hydrogen’ means a hydrogen storage technology which stores hydrogen at temperatures from close to liquefication up to ambient temperature and at a pressure of at least 200 bar. The hydrogen storage technology may be capable of operating at ambient temperature but its nominal fill density may only be reached close to the liquefaction temperature of hydrogen;

(46) ‘empty hydrogen tank condition’ means the condition of a hydrogen tank from which it is still possible to reach a full tank in a single refuelling event without venting and which meets any of the following conditions:

(a) below which an indication to the driver ‘empty’ or ‘almost empty’ or similar appears;

(b) below which a significantly limited performance is provided by the hydrogen energy conversion system;

(47) ‘off-vehicle charging fuel cell hybrid vehicle’ or ‘OVC-HV’ means a hybrid vehicle that can be charged from an external source;

(48) ‘off-vehicle charging hybrid vehicle’ or ‘OVC-FCHV’ means a fuel cell hybrid vehicle that can be charged from an external source;

(49) ‘driver-selectable mode’ means a distinct driver-selectable condition which could affect emissions, or fuel and/or energy consumption;

(50) ‘predominant mode’ means a single driver-selectable mode that is always selected when the vehicle is switched on, regardless of the driver-selectable mode in operation when the vehicle was previously shut down, which meets the following conditions:

(a) it cannot be redefined to another mode;

(b) it can only be switched to another driver-selectable mode by an intentional action of the driver after the vehicle is switched on;

(51) ‘battery-only predominant mode’ means a predominant mode where an OVC-HV is operating with the propulsion energy being provided exclusively by the REESS.’;

(2) in point 3, first paragraph, the first sentence is replaced by the following:

‘In tables 1 to 17 the sets of input parameters to be provided regarding the characteristics of the vehicle are specified.’;

(3) table 1 is amended as follows:

(a) in row ‘IdlingSpeed’, in column ‘Description/Reference’ the second sentence is replaced by the following:

‘For PEV and FCHV no input is required’;

(b) in row ‘RetarderType’, in column ‘Description/Reference’ the text is replaced by the following:

‘Allowed values: ‘None’, ‘Losses included in Gearbox’, ‘Engine Retarder’, ‘Transmission Input Retarder’, ‘Transmission Output Retarder’, ‘Axlegear Input Retarder’

‘Axlegear Input Retarder’ is applicable only for powertrain architectures ‘E3’, ‘S3’, ‘F3, ‘S-IEPC’, ‘F-IEPC’ and ‘E-IEPC’.

Separate entry for each individual powertrain in the case of multiple mechanically independent powertrains in accordance with point 10.1.4.’;

(c) in rows ‘RetarderRatio’ and ‘AngledriveType’, in column ‘Description/Reference’, the following text is added:

‘Separate entry for each individual powertrain in the case of multiple mechanically independent powertrains in accordance with point 10.1.4.’;

(d) in row ‘PTOShafts GearWheels’, in column ‘Description/Reference’, the following text is added:

'Separate entry for each individual powertrain in the case of multiple mechanically independent powertrains in accordance with point 10.1.4.

In case of IEPS and IHPC, no input shall be made.';

(e) in row 'PTOOther Elements', in column 'Description/Reference', the following text is added:

'Separate entry for each individual powertrain in the case of multiple mechanically independent powertrains in accordance with point 10.1.4.';

(f) in row 'CertificationNumberEngine', in columns 'Parameter name', 'Parameter ID', 'Type' and 'Unit', the four cells are merged together and the text of the four cells is replaced by the following:

'Engine input data in accordance with Appendix 7 of Annex V';

(g) in row 'CertificationNumberGearbox', in columns 'Parameter name', 'Parameter ID', 'Type' and 'Unit', the four cells are merged together and the text in the four cells is replaced by the following:

'Transmission input data in accordance with table 1 to table 3 in Appendix 12 of Annex VI';

(h) in row 'CertificationNumberGearbox', in column 'Description/Reference' the text is replaced by the following:

'Only applicable if the component is present in the vehicle. Separate entry for each individual powertrain in the case of multiple mechanically independent powertrains in accordance with point 10.1.4';

(i) in row 'CertificationNumberTorqueconverter', in columns 'Parameter name', 'Parameter ID', 'Type' and 'Unit', the four cells are merged together and the text of the four cells is replaced by the following:

'Torque converter input data in accordance with table 4 and table 5 in Appendix 12 of Annex VI';

(j) in row 'CertificationNumberTorqueconverter', in column 'Description/Reference' the text is replaced by the following:

'Only applicable if the component is present in the vehicle. Separate entry for each individual powertrain in the case of multiple mechanically independent powertrains in accordance with point 10.1.4';

(k) in row 'CertificationNumberAxlegear', in columns 'Parameter name', 'Parameter ID', 'Type' and 'Unit', the four cells are merged together and the text of the four cells is replaced by the following:

'Axle input data in accordance with table 1 and table 2 in Appendix 6 of Annex VII';

(l) in row 'CertificationNumberAxlegear', in column 'Description/Reference' the text is replaced by the following:

'Only applicable if the component is present in the vehicle. Separate entry for each individual powertrain in the case of multiple mechanically independent powertrains in accordance with point 10.1.4';

(m) in row ‘CertificationNumberAngledrive’, in columns ‘Parameter name’, ‘Parameter ID’, ‘Type’ and ‘Unit’, the four cells are merged together and the text of the four cells is replaced by the following:

‘Angle drive input data in accordance with table 6 and table 7 in Appendix 12 of Annex VI’;

(n) in row ‘CertificationNumberAngledrive’, in column ‘Description/Reference’ the text is replaced by the following:

‘Refers to certified ADC component installed in the angle drive position. Only applicable if the component is present in the vehicle. Separate entry for each individual powertrain in the case of multiple mechanically independent powertrains in accordance with point 10.1.4.’;

(o) in row ‘CertificationNumberRetarder’, in columns ‘Parameter name’, ‘Parameter ID’, ‘Type’ and ‘Unit’, the four cells are merged together and the text of the four cells is replaced by the following:

‘Retarder input data in accordance with table 8 and table 9 in Appendix 12 of Annex VI’;

(p) in row ‘CertificationNumberRetarder’, in column ‘Description/Reference’ the text is replaced by the following:

‘Only applicable if the component is present in the vehicle and the retarder losses are not provided together with the input data for the transmission component. Separate entry for each individual powertrain in the case of multiple mechanically independent powertrains in accordance with point 10.1.4.’;

(q) in row ‘Certification NumberAirdrag’, in columns ‘Parameter name’, ‘Parameter ID’, ‘Type’ and ‘Unit’, the four cells are merged together and the text of the four cells is replaced by the following:

‘Air drag input data in accordance with table 1 in Appendix 9 of Annex VIII’;

(r) in row ‘Certification NumberIEPC’, in columns ‘Parameter name’, ‘Parameter ID’, ‘Type’ and ‘Unit’, the four cells are merged together and the text of the four cells is replaced by the following:

‘IEPC input data in accordance with Appendix 15 of Annex Xb’;

(s) in row ‘Certification NumberIEPC’, in column ‘Description/Reference’ the text is replaced by the following:

‘Only applicable if the component is present in the vehicle. Separate entry for each individual powertrain in the case of multiple mechanically independent powertrains in accordance with point 10.1.4’;

(t) in the row ‘BodyworkCode’, in the column ‘Description/Reference’, the text is replaced by the following:

‘Allowed values: ‘CA’, ‘CB’, ‘CC’, ‘CD’, ‘CE’, ‘CF’, ‘CG’, ‘CH’, ‘CI’, ‘CJ’ in accordance with point 3 of part C of Annex I to Regulation (EU) 2018/858. In the case of bus chassis with vehicle code CX, no input shall be delivered.’;

(u) in the row ‘LowEntry’, in the column ‘Description/Reference’, the text is replaced by the following:

‘‘low entry’ in accordance with point 1.2.3. of Annex I’;

(v) the following rows are added:

‘

H2StorageUsableCapacity	PXXX	double, 1	[kg]	In accordance with point 12. Only relevant for vehicles with a fuel storage system containing hydrogen. For heavy buses, the input shall only be provided by the manufacturer responsible for the fuel storage system or if changes have been made to an existing fuel storage system.	X	X	X	X
HydrogenStorageTechnology	PXXX	string	[-]	Allowed values: ‘Compressed’, ‘Liquid’, ‘Cryo-compressed’ Only relevant for vehicles with a fuel storage system containing hydrogen. For heavy buses, the input shall only be provided by the manufacturer responsible for the fuel storage system or if changes have been made to an existing fuel storage system.	X	X	X	X
SimulationToolLicenceNumber	PXXX	token	[-]	License number related to the operation of the simulation tool in accordance with Article 7.	X	X	X	X

’;

(4) table 2 is amended as follows:

(a) the following row is inserted before the row ‘Twin Tyres’:

‘

AxleNumber	PXXX	integer	[-]	Position of the wheel axle on the vehicle, counting from the front to the rear starting with 1	X	X	X	

’;

(b) the row ‘Certification NumberTyre’ is replaced by the following:

‘

Tyre input data in accordance with Appendix 3 of Annex X		X	X	X	

’;

(c) the following rows are added:

‘

Wheel End Friction	PXXX	double, 1	[Nm]	Declared wheel end friction value Determined in accordance with point 3.6 in Annex VIIa. The	X		X	

				wheel ends installed in the vehicle shall have the same or lower friction values. In the case of standard values no input shall be provided. Input only relevant for non-driven axles.				
Certification number wheel end	PXXX	token	[-]	Certification number(s) of the certificate(s) for the declared wheel end friction referred to by the input on wheel end friction (PXXX) Input only relevant for axles where an input on wheel end friction is actually provided. Multiple entries possible.	X		X	

’;

(5) table 3 is amended as follows:

(a) in row ‘EngineCoolingFan/Technology’, in column ‘Description/Reference’ the text is replaced by the following:

‘Allowed values: ‘Crankshaft mounted - Electronically controlled visco clutch’, ‘Crankshaft mounted - Bimetallic controlled visco clutch’, ‘Crankshaft mounted - Discrete step clutch’, ‘Crankshaft mounted - On/off clutch’, ‘Belt driven or driven via transm. - Electronically controlled visco clutch’, ‘Belt driven or driven via transm. - Bimetallic controlled visco clutch’, ‘Belt driven or driven via transm. - Discrete step clutch’, ‘Belt driven or driven via transm. - On/off clutch’, ‘Hydraulic driven - Variable displacement pump’, ‘Hydraulic driven - Constant displacement pump’, ‘Electrically driven - Electronically controlled’’;

(b) in row ‘SteeringPump/Technology’, in column ‘Description/Reference’ the text is replaced by the following:

‘Allowed values: ‘Fixed displacement’, ‘Fixed displacement with elec. control’, ‘Dual displacement’, ‘Dual displacement with elec. control’, ‘Variable displacement mech. controlled’, ‘Variable displacement elec. controlled’, ‘Electric driven pump’, ‘Full electric steering gear’
For PEV, FCHV or HEV with a powertrain configuration ‘S’ or ‘S-IEPC’ in accordance with point 10.1.1 ‘Electric driven pump’ or ‘Full electric steering gear’ are the only allowed values.
Separate entry for each active steered wheel axle required in combination with axle position counting from the front to the rear starting with 1.’;

(c) in row ‘PneumaticSystem/Technology’, in column ‘Description/Reference’ the text is replaced by the following:

‘Allowed values: ‘Small’, ‘Small + ESS’, ‘Small + visco clutch’, ‘Small + mech. clutch’, ‘Small + ESS + AMS’, ‘Small + visco clutch + AMS’, ‘Small + mech. clutch + AMS’, ‘Medium Supply 1-stage’, ‘Medium Supply 1-stage + ESS’, ‘Medium Supply 1-stage + visco clutch ’, ‘Medium Supply 1-stage + mech. clutch’, ‘Medium Supply 1-stage + ESS + AMS’, ‘Medium Supply 1-stage + visco clutch + AMS’, ‘Medium Supply 1-stage + mech. clutch + AMS’, ‘Medium Supply 2-stage’, ‘Medium Supply 2-stage + ESS’, ‘Medium Supply 2-stage + visco clutch ’, ‘Medium Supply 2-

stage + mech. clutch', 'Medium Supply 2-stage + ESS + AMS', 'Medium Supply 2-stage + visco clutch + AMS', 'Medium Supply 2-stage + mech. clutch + AMS', 'Large Supply', 'Large Supply + ESS', 'Large Supply + visco clutch', 'Large Supply + mech. clutch', 'Large Supply + ESS + AMS', 'Large Supply + visco clutch + AMS', 'Large Supply + mech. clutch + AMS', 'Vacuum pump', 'Small + elec. driven', 'Small + ESS AMS + elec. driven', 'Medium Supply 1-stage + elec. driven', 'Medium Supply 1-stage + AMS + elec. driven', 'Medium Supply 2-stage + elec. driven', 'Medium Supply 2-stage + AMS + elec. driven', 'Large Supply + elec. driven', 'Large Supply + AMS + elec. driven', 'Vacuum pump + elec. driven'; For PEV or FCHV only 'elec. driven' technologies are allowed values.';

(6) table 3a is amended as follows:

(a) in row 'EngineCoolingFan/Technology', in column 'Description/Reference' the text is replaced by the following:

'Allowed values: 'Crankshaft mounted - Electronically controlled visco clutch', 'Crankshaft mounted - Bimetallic controlled visco clutch', 'Crankshaft mounted - Discrete step clutch 2 stages', 'Crankshaft mounted - Discrete step clutch 3 stages', 'Crankshaft mounted - On/off clutch', 'Belt driven or driven via transm. - Electronically controlled visco clutch', 'Belt driven or driven via transm. - Bimetallic controlled visco clutch', 'Belt driven or driven via transm. - Discrete step clutch 2 stages', 'Belt driven or driven via transm. - Discrete step clutch 3 stages', 'Belt driven or driven via transm. - On/off clutch', 'Hydraulic driven - Variable displacement pump', 'Hydraulic driven - Constant displacement pump', 'Electrically driven - Electronically controlled'';

(b) in row 'SteeringPump/Technology', in column 'Description/Reference' the text is replaced by the following:

'Allowed values: 'Fixed displacement', 'Fixed displacement with elec. control', 'Dual displacement', 'Dual displacement with elec. control', 'Variable displacement mech. controlled', 'Variable displacement elec. controlled', 'Electric driven pump', 'Full electric steering gear'
For PEV, FCHV or HEV with a powertrain configuration 'S' or 'S-IEPC' in accordance with point 10.1.1 only 'Electric driven pump' or 'Full electric steering gear' are allowed values
Separate entry for each active steered wheel axle required in combination with axle position counting from the front to the rear starting with 1.';

(c) in row 'ElectricSystem/AlternatorTechnology', in column 'Description/Reference' the following text is added:

'For PEV or FCHV no input is required.';

(d) in row 'ElectricSystem/SupplyFromHEVPossible', in column 'Description/Reference' the following text is added:

'Input only required for HEV in combination with alternator technology "conventional" or "smart".';

(e) in row 'PneumaticSystem/SizeOfAirSupply', in column 'Description/Reference' the text is replaced by the following:

'Allowed values: 'Small', 'Medium Supply 1-stage', 'Medium Supply 2-stage', 'Large Supply 1-stage', 'Large Supply 2-stage', 'not applicable'

For electrically driven compressor 'not applicable' shall be provided. For PEV or FCHV no input is required.';

(f) in row 'PneumaticSystem/CompressorDrive', in column 'Description/Reference' the text is replaced by the following:

'Allowed values: 'mechanically', 'electrically' For PEV or FCHV, only 'electrically' is an allowed value.';

(g) in row 'PneumaticSystem/Clutch', in column 'Description/Reference' the text is replaced by the following:

'Allowed values: 'none', 'visco', 'mechanically' For PEV or FCHV no input is required.';

(h) in row 'PneumaticSystem/SmartCompressionSystem', in column 'Description/Reference' the text is replaced by the following:

'For PEV, FCHV or HEV with a powertrain configuration 'S' or 'S-IEPC' in accordance with point 10.1.1 no input is required.';

(i) in row 'PneumaticSystem/Ratio Compressor ToEngine', in column 'Description/Reference' the text is replaced by the following:

'For electrically driven compressor '0.000' shall be provided. For PEV or FCHV no input is required.';

(j) in row 'HVAC/EngineWasteGasHeatExchanger', in column 'Description/Reference' the text is replaced by the following:

'For PEV or FCHV no input is required.';

(k) in rows 'HVAC/WaterElectricHeater', 'HVAC/AirElectricHeater' and 'HVAC/OtherHeating Technology', in column 'Description/Reference' the text is replaced by the following:

'Input to be provided only for HEV, FCHV and PEV';

(7) table 4 is amended as follows:

(a) the heading is replaced by the following:

'Input parameters 'VehicleTorqueLimits' per gear (optional)';

(b) in row 'Gear', in column 'Description/Reference' the text is replaced by the following:

'Only gear numbers need to be specified where vehicle related torque limits according to point 6 are applicable.';

(c) in row 'MaxTorque', in column 'Description/Reference' the following text is inserted:

'Maximum engine or transmission input torque for the specific gear defined in accordance with point 6.';

(8) table 5 is amended as follows:

(a) in row 'BodyworkCode', in column 'Description/Reference' the text is replaced by the following:

'Allowed values: 'CA', 'CB', 'CC', 'CD', 'CE', 'CF', 'CG', 'CH', 'CI', 'CJ' in accordance with point 3 of part C of Annex I to Regulation (EU) 2018/858';

(b) in row ‘Technology’, in column ‘Description/Reference’ the text is replaced by the following:

‘In accordance with table 1 of Appendix 1. Allowed values: ‘FCV Article 9 exempted’, ‘Dual-fuel vehicle Article 9 exempted’, ‘HEV Article 9 exempted’, ‘PEV Article 9 exempted’, ‘In-motion charging Article 9 exempted’, ‘Multiple powertrains Article 9 exempted’, ‘H2 ICE Article 9 exempted’, ‘HV Article 9 exempted’, ‘Other technology Article 9 exempted’’;

(c) the following row is added:

‘

SimulationToolLicenceNumber	PXXX	token	[-]	License number related to the operation of the simulation tool in accordance with Article 7.	X	X	X	X

’;

(9) table 6 is amended as follows:

(a) row ‘EngineStopStart’, column ‘Description/Reference’ the following text is added:

‘For OVC-HEV the input shall be set to ‘true’.’;

(b) row ‘PredictiveCruiseControl’, column ‘Description/Reference’ the text is replaced by the following:

‘In accordance with point 8.1.4, allowed values: ‘none’, ‘1,2’, ‘1,2,3’’;

(10) table 7 is replaced by the following:

‘*Table 7*

General input parameters for HEV, PEV and FCHV

Parameter name	**Parameter ID**	**Type**	**Unit**	**Description/Reference**	**Heavy lorries**	**Medium lorries**	**Heavy buses (primary vehicle)**	**Heavy buses (complete or completed vehicle)**
ArchitectureID	P400	string	[-]	In accordance with point 10.1.3, the following values are allowed inputs: ‘E2’, ‘E3’, ‘E4’, ‘E-IEPC’, ‘P1’, ‘P2’, ‘P2.5’, ‘P3’, ‘P4’, ‘S2’, ‘S3’, ‘S4’, ‘S-IEPC’, ‘F2’, ‘F3’, ‘F4’, ‘F-IEPC’	X	X	X	
ArchitectureIDPwt2	PXXX	string	[-]	In the case of multiple mechanically independent powertrains in accordance with point 10.1.4, the architecture ID of the second powertrain shall be	X		X	

Parameter name	Parameter ID	Type	Unit	Description/Reference	Heavy lorries	Medium lorries	Heavy buses (primary vehicle)	Heavy buses (complete or completed vehicle)
				provided. In accordance with points 10.1.3 and 10.1.4, the following values are allowed inputs: ‘E2’, ‘E3’, ‘E4’, ‘E-IEPC’, ‘S2’, ‘S3’, ‘S4’, ‘S-IEPC’, ‘F2’, ‘F3’, ‘F4’, ‘F-IEPC’				
OVC	PXXX	boolean	[-]	Vehicle where the REESS can be charged from an external source. Shall be set to true for: • OVC-HEV • PEV • OVC-FCHV in case the charging device is also designed for normal operation of the vehicle and not just for service purposes	X	X	X	
BatteryOnlyMode	PXXX	boolean	[-]	To be declared for HV in accordance with point 2(50). For PEV this input shall always be set to ‘true’.	X	X	X	
Dynamic Charging Technology	PXXX	string	[-]	Allowed values: ‘None’, ‘Overhead pantograph’, ‘Overhead trolley’, ‘Ground rail’, ‘Wireless’ ‘Overhead pantograph’ is not applicable to medium lorries. ‘Overhead trolley’ is only applicable to heavy buses.	X	X	X	X

’;

(11) table 8 is amended as follows:

(a) the heading and the introductory wording are replaced by the following:

‘Input parameters per electric machine position

Separate entry for each individual powertrain in the case of multiple mechanically independent powertrains in accordance with point 10.1.4. (Only applicable if the component is present in the vehicle or in the specific powertrain)’;

(b) the row ‘CertificationNumberEM’ is replaced by the following, whereby the first four columns of this row are merged together:

‘

Electric machine system input data in accordance with Appendix 15 of Annex Xb	

’;

(c) the row ‘CertificationNumberADC’ is replaced by the following, whereby the first four columns of this row are merged together:

‘

ADC input data in accordance with Appendix 12 of Annex VI	Optional input in the case of additional single-step gear ratio (ADC) between EM shaft and connection point to vehicle’s powertrain according to point 10.1.2 In case of EMS connected via belt the provisions in accordance with point 6.1.3 of Annex VI shall apply. Not allowed where parameter ‘IHPCType’ is set to ‘IHPC Type 1’.

’;

(12) in table 9, the following paragraph is added after the introductory paragraph:

‘Separate entry for each individual powertrain in the case of multiple mechanically independent powertrains in accordance with point 10.1.4.’

(13) table 10 is replaced by the following:

‘*Table 10*

Input parameters per REESS

(Only applicable if the component is present in the vehicle)

Parameter name	**Parameter ID**	**Type**	**Unit**	**Description/Reference**
StringID	P411	integer	[-]	The arrangement of representative battery sub-systems in accordance with Annex Xb on vehicle level shall be declared by allocation of each battery sub-system to a specific string defined by this parameter. All specific strings are connected in parallel, all battery sub-system located in one specific parallel string are connected in series. Allowed values: ‘1’, ‘2’, ‘3’, …
REESS input data in accordance with Appendix 15 of Annex Xb				
DeteriorationPerformanceRatio	PXXX	double, 2	[%]	For PEV and OVC-HV either the minimum performance requirement (MPR) applicable to the vehicle in main lifetime according to table 3 of Annex II of Regulation (EU) 2024/1257 of the European Parliament and of the Council[(1)] or a declared performance requirement (DPR) higher than the MPR shall be declared as input, if in turn such DPR is declared by the

Parameter name	Parameter ID	Type	Unit	Description/Reference
				manufacturer and assessed for the vehicle in main lifetime according to the provisions of Regulation (EU) 2024/1257 and its implementing legislation. For HV which are not OVC-HV no input shall be provided.
SOCmin	P413	double, 1	[%]	Only relevant in the case of REESS type 'battery'. For PEV and for OVC-HV with a battery-only predominant mode in accordance with point 2(50) this input shall be declared as percentage of the rated capacity when zero (or other low limit defined by OEM) remaining battery charge is indicated to the driver or if normal vehicle operation[(2)] in battery-only predominant mode is not possible due to low battery charge. For HV which are not OVC-HV and for OVC-HV without a battery-only predominant mode in accordance with point 2(50) this input is optional and the parameter is only effective in the simulation tool where the input is higher than generic value as documented in the user manual.
SOCmax	P414	double, 1	[%]	Only relevant in the case of REESS type 'battery'. For PEV and for OVC-HV with a battery-only predominant mode in accordance with point 2(50) this input shall be declared as percentage of the rated capacity when the vehicle is indicated as fully charged to the driver. For HV which are not OVC-HV and for OVC-HV without a battery-only predominant mode in accordance with point 2(50) this input is optional and the parameter is only effective in the simulation tool where the input is lower than generic value as documented in the user manual.

(1) Regulation (EU) 2024/1257 of the European Parliament and of the Council of 24 April 2024 on type-approval of motor vehicles and engines and of systems, components and separate technical units intended for such vehicles, with respect to their emissions and battery durability (Euro 7), amending Regulation (EU) 2018/858 of the European Parliament and of the Council and repealing Regulations (EC) No 715/2007 and (EC) No 595/2009 of the European Parliament and of the Council, Commission Regulation (EU) No 582/2011, Commission Regulation (EU) 2017/1151, Commission Regulation (EU) 2017/2400 and Commission Implementing Regulation (EU) 2022/1362 (OJ L, 2024/1257, 8.5.2024, ELI: http://data.europa.eu/eli/reg/2024/1257/oj).

(2) 'normal vehicle operation' shall exclude any significant limitation of operation (e.g. 'limp home operation' shall not be considered normal vehicle operation).';

(14) the following table is inserted after Table 11:

'*Table 11a*

Input parameters per fuel cell system

(Only applicable if the component is present in the vehicle)

One or two different fuel cell systems, each may have up to 3 identical units installed.

Parameter name	Parameter ID	Type	Unit	Description/Reference
Count	PXXX	integer	[-]	Number of identical units, allowed values: '1', '2', '3'
MinPower	PXXX	integer	[W]	Optional input for declaration of applicable lower power limit of fuel cell system on vehicle integration level.
MaxPower	PXXX	integer	[W]	Optional input for declaration of applicable upper power limit of fuel cell system on vehicle integration level.
fuel cell system input data in accordance with Appendix 15 of Annex Xb				

';

(15) point 6 is replaced by the following:

'**6. Gear dependent torque limits and gear disabling**';

(16) point 6.2. is replaced by the following:

'6.2 Gear disabling

Either for the highest gear only or for both of the highest two gears (e.g. gear 5 and 6 for a 6-gear transmission) the vehicle manufacturer may declare a complete disabling of gears by providing 0 Nm as gear specific torque limit in the input to the simulation tool. Declaring such gear disabling only for the second highest gear is not allowed.';

(17) point 10 is replaced by the following:

'**10. HEV, FCHV and PEV**

The following provisions shall apply only in the case of HEV, FCHV and PEV.';

(18) in point 10.1.1 the following paragraph is added:

'In the case of a FCHV:

(a) 'F' in the case an EM component is present in the vehicle

(b) 'F-IEPC' in the case an IEPC component is present in the vehicle';

(19) in point 10.1.2 the first paragraph is replaced by the following:

'Where the configuration of the vehicle's powertrain in accordance with point 10.1.1 is 'P', 'S', 'F' or 'E', the position of the EM installed in the vehicle's powertrain shall be determined in accordance with the definitions set out in table 14.';

(20) table 14 is amended as follows:

(a) in row '2', in the column 'Powertrain configuration in accordance with point 10.1.1', the text is replaced by the following:

'E, S, F';

(b) in the second row '3', in the column 'Powertrain configuration in accordance with point 10.1.1', the text is replaced by the following:

‘E, S, F’;

(c) in the second row ‘4’, in the column ‘Powertrain configuration in accordance with point 10.1.1’, the text is replaced by the following:

‘E, S, F’;

(21) in table 15, the following entry is added:

‘

FCHV	F	F2	no	no	no	yes	yes	no	yes	no	
		F3	no	no	no	no	no	yes	yes	no	
		F4	no	no	no	no	no	no	no	yes	
		F-IEPC	no	no	no	no	no	no	[5]	no	

[5] ‘Yes’ (i.e. axle component present) only in the case that both parameters ‘DifferentialIncluded’ and ‘DesignTypeWheelMotor’ are set to ‘false’’;

(22) the following point is inserted after table 15:

‘10.1.4 Definition of architecture ID for second mechanically independent powertrain

In case the vehicle is equipped with two powertrains where each powertrain is propelling different wheel axles of the vehicle and where these different powertrains can under no circumstances be mechanically connected, the vehicle manufacturer shall declare a second powertrain ID defined in accordance with point 10.1.3. Additionally, the two powertrains shall share the same REESS and separate electrical to mechanical energy converters.

In this regard hydraulically driven axles shall, in accordance with point 5, second subparagraph, point (a) of this Annex, be treated as non-driven axles and shall thus not be counted as a mechanically independent powertrain.

Only powertrains of configuration S, S-IEPC, F, F-IEPC and E, in accordance with point 10.1.1, shall be allowed to be declared in case of presence of a second mechanically independent powertrain. Furthermore, only the combinations of architecture IDs for the first and second powertrain indicated with ‘yes’ in table 15a may be declared.’;

(23) the following table is inserted after point 10.1.4:

‘*Table 15a*

Valid inputs of powertrain architecture into the simulation tool

ArchitectureIDPwt2 / Architecture ID	E2	E3	E4	E-IEPC	S2	S3	S4	S-IEPC	F2	F3	F4	F-IEPC
E2	yes	yes	yes	yes	no	no	no	no	no	no	no	no
E3	yes	yes	yes	yes	no	no	no	no	no	no	no	no
E4	yes	yes	yes	yes	no	no	no	no	no	no	no	no
E-IEPC	yes	yes	yes	yes	no	no	no	no	no	no	no	no
S2	no	no	no	no	yes	yes	yes	yes	no	no	no	no
S3	no	no	no	no	yes	yes	yes	yes	no	no	no	no
S4	no	no	no	no	yes	yes	yes	yes	no	no	no	no
S-IEPC	no	no	no	no	yes	yes	yes	yes	no	no	no	no
F2	no	no	no	no	no	no	no	no	yes	yes	yes	yes
F3	no	no	no	no	no	no	no	no	yes	yes	yes	yes
F4	no	no	no	no	no	no	no	no	yes	yes	yes	yes
F-IEPC	no	no	no	no	no	no	no	no	yes	yes	yes	yes

’;

(24) the following points are added after point 11.5.:

‘**12. Usable capacity of the hydrogen fuel storage system**

For fuel storage systems containing hydrogen the usable capacity shall be determined.

12.1 Compressed gaseous hydrogen

The usable capacity shall be calculated based on the following equation:

$$m_{usable} = V_{CHSS} \cdot \left(\rho_{15°C,\ NWP} - \rho_{15°C,\ p_{min,rel}}\right) \cdot 0{,}001$$

where:

m_{usable}	usable capacity [kg]
V_{CHSS}	volume of the compressed hydrogen storage technology [l]
$p_{min,rel}$	relative pressure corresponding to empty hydrogen tank condition [MPa]
$\rho_{15°C,\ NWP}$	density of the compressed gaseous hydrogen at 15°C and at nominal working pressure (NWP) as defined in point 2.17. of UN Regulation No. 134 [g/l] This density value shall be determined from table 16 by linear interpolation.
$\rho_{15°C,\ pmin,rel}$	density of the compressed gaseous hydrogen at 15°C and at $p_{min,rel}$ [g/l] This density value shall be determined from table 16 by linear interpolation.

Table 16

Density of compressed hydrogen at 15°C [g/l]

Temperature (°C)	***Pressure (MPa)***												
	0,5	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**35**	**70**
15	0,5	0,9	1,7	2,6	3,4	4,2	4,9	5,7	6,5	7,3	8,0	24,0	40,2

12.2 Liquid hydrogen

The usable capacity shall be calculated based on the following equation:

$$m_{usable} = V_{LHSS} \cdot \left(\rho_{full,ref} - \rho_{empty}\right) \cdot 0{,}001$$

where:

m_{usable}	usable capacity [kg]
V_{LHSS}	volume of the liquid hydrogen storage technology [l]
$\rho_{full\ ref}$	density of the liquid hydrogen corresponding to full hydrogen tank condition [g/l], defined by the following operational conditions: (a) the vehicle is operated until the empty hydrogen tank condition is reached. (b) the refilling starts immediately afterwards. (c) with regard to the state of the hydrogen as provided by the hydrogen refuelling infrastructure, reference shall be made to international standards, if available.

ρ_{empty}	density of the liquid hydrogen corresponding to the empty hydrogen tank condition [g/l]

The calculation model of the densities shall be disclosed to the approval authority on request.

12.3 Cryo-compressed hydrogen

The usable capacity shall be calculated based on the following equations:

$$m_{usable} = V_{CCHSS} \cdot \rho_{filling} \cdot f_{usable} \cdot 0{,}001$$

$$\rho_{filling} = 0{,}0589 \cdot p_{filling} + 52{,}395$$

where:

m_{usable}	usable capacity [kg]
V_{CCHSS}	volume of the cryo-compressed hydrogen storage technology [l]
$\rho_{filling}$	density of the hydrogen at the end of the refuelling process [g/l]
f_{usable}	usable share determined from table 17 by linear interpolation [-]
$p_{filling}$	absolute hydrogen pressure in the tank at the end of the refuelling process [bar]

The value for hydrogen pressure in the tank at the end of the refuelling process used in the calculations shall be documented in the information document for the cryo-compressed hydrogen tank system. Existing international standards on cryo-compressed refuelling infrastructure shall be taken into account when determining this value, if already available.

Table 17

Usable share of the hydrogen mass in a cryo-compressed hydrogen storage technology [-]

Absolute pressure corresponding to empty hydrogen tank condition [bar]	**f_{usable}* [-]**
5	0,97
8	0,95
10	0,93
15	0,88
20	0,85
30	0,75
* The specified values for f_{usable} assume that the tank has an internal heating system that is activated when the minimum pressure is reached. Where there is no such in-tank heating	

system, the manufacturer shall apply, upon approval from the approval authority, a lower value for f_{usable}.

’;

(25) in Appendix 1, table 1 is amended as follows:

(a) in row ‘Fuel cell vehicle’, in column ‘Criteria for exemption’ the text is replaced by the following:

‘Vehicles shall be exempted where at least one of the following criteria apply:

- A fuel cell vehicle which is not a fuel cell hybrid vehicle in accordance with point 2 (13) of this Annex.

- The vehicle is equipped with multiple EMs located within a single powertrain which are not placed at the same connection point in the drivetrain in accordance with point 10.1.2 of this Annex;

- The vehicle is equipped with multiple EMs located within a single powertrain which are placed at the same connection point in the drivetrain in accordance with point 10.1.2 of this Annex but do not have identical specifications (i.e. the same component certificate).

- The vehicle has a powertrain architecture other than F2 to F4 or F-IEPC in accordance with point 10.1.3 of this Annex.

’;

(b) the row ‘ICE operated with hydrogen’ is deleted;

(c) in row ‘Dual-fuel’, in column ‘Criteria for exemption’ the text is replaced by the following:

‘Dual-fuel vehicles with an engine operated with natural gas or LPG being of types 1B, 2B and 3B as defined in Article 2(53), 2(55) and 2(56) of Regulation (EU) No 582/2011 or dual-fuel vehicles with an engine operated with hydrogen being of a type other than 1A as defined in Article 2(52) of Regulation (EU) No 582/2011.’;

(d) in row ‘HEV’, in column ‘Criteria for exemption’ the text is replaced by the following:

‘Vehicles shall be exempted where at least one of the following criteria apply:

- The vehicle is equipped with multiple EMs located within a single powertrain which are not placed at the same connection point in the drivetrain in accordance with point 10.1.2 of this Annex.

- The vehicle is equipped with multiple EMs located within a single powertrain which are placed at the same connection point in the drivetrain in accordance with point 10.1.2 of this Annex but do not have identical specifications (i.e. the same component certificate).

- The vehicle has a powertrain architecture other than P1 to P4, S2 to S4, S-IEPC in accordance with point 10.1.3 of this Annex or other than IHPC Type 1.’;

(e) in row ‘PEV’, in column ‘Criteria for exemption’ the text is replaced by the following:

‘Vehicles shall be exempted where at least one of the following criteria apply:

- The vehicle is equipped with multiple EMs located within a single powertrain which are not placed at the same connection point in the drivetrain in accordance with point 10.1.2 of this Annex.

- The vehicle is equipped with multiple EMs located within a single powertrain which are placed at the same connection point in the drivetrain in accordance with point 10.1.2 of this Annex but do not have identical specifications (i.e. the same component certificate).

- The vehicle has a powertrain architecture other than E2 to E4 or E-IEPC in accordance with point 10.1.3 of this Annex.';

(f) in row 'Multiple permanently mechanically independent powertrains', in column 'Criteria for exemption' the first paragraph is replaced by the following:

'The vehicle is equipped with more than one powertrain where each powertrain is propelling different wheel axle(s) of the vehicle and where different powertrains can under no circumstances be mechanically connected and where the specific system is not covered by the allowed combinations defined in point 10.1.4 of this Annex.';

(g) the row 'in-motion charging' is deleted;

(h) the following row is added:

'

Other	Any other propulsion technology that is not listed in this table for which it is not possible to perform a simulation in accordance with Article 9 of this Regulation due to limitations of the simulation tool regarding this specific propulsion technology.	'Other technology Article 9 exempted'

'.

ANNEX III

Annex IV is amended as follows:

(1) in point 2 the following subpoint is added:

'(4) 'hydrogen range': The range that can be driven based on the usable amount of hydrogen.';

(2) point 3 is amended as follows:

(a) Part I is amended as follows:

(a) the following point is inserted after point 1.1.15.:

'1.1.15a. FCHV architecture (e.g. F2, F3) ....';

(b) point 1.1.18. deleted;

(c) point 1.1.29. is replaced by the following:

'1.1.29. Tank system in the case of natural gas or hydrogen (e.g. compressed, liquified) …';

(d) points 1.1.31. and 1.1.32 are inserted after point 1.1.30.:

‘1.1.31. Vehicle type approval number ....

1.1.32. Simulation tool licence number ....’;

(e) the following points are inserted after point 1.8.3.:

‘1.8.3a. CFD method licence number (if applicable) ....

1.8.3b. Delta CdxA from CFD (if applicable) ....’;

(f) points 1.10.5.2. to 1.10.5.5 are replaced by the following:

‘1.10.5.2. Heat pump type driver compartment cooling ....

1.10.5.3. Heat pump type driver compartment heating ....

1.10.5.4. Heat pump type passenger compartment cooling ....’;

1.10.5.5. Heat pump type passenger compartment heating ....’;

(g) point 1.10.5.7. is replaced by the following:

‘1.10.5.7. Double glazing (yes/no) ....’;

(h) the following point is inserted after point 1.13.15.:

‘1.13.16 Boosting limitations ....’;

(i) the following point is added after point 1.14.7.:

‘1.14.7a. Design type wheel motors (yes/no) ....’;

(j) point 1.15. is replaced by the following:

‘1.15. Rechargeable Energy Storage Systems specifications - Battery’;

(k) point 1.15.6. is replaced by the following:

‘1.15.6. Certification method (measured, standard values) ....’;

(l) the following points are inserted after point 1.15.8.:

‘1.16. Rechargeable Energy Storage Systems specifications – Capacitor

1.16.1. Model ....

1.16.2. Certification number ....

1.16.3. Capacitance (F) ....

1.16.4. Minimum voltage (V) ....

1.16.5. Maximum voltage (V) ....

1.16.6. Hash of the input data and input information ....

1.16.7. Certification method (measured, standard values) …………………

1.17. Fuel Cell System(s) specifications

1.17.1. Model ....

1.17.2. Certification number ....

1.17.3. Certification method (measured, standard values) ....

1.17.4. Rated power (kW) ....

1.17.5. Count ....’;

(m) point 2.1. is replaced by the following:

‘2.1. Simulation parameters (for each mission profile and loading combination, for OVC-HEVs separately for charge depleting mode, charge sustaining mode and weighted, for OVC-FCHV separately for charge depleting mode and charge sustaining mode)’;

(n) the following point is inserted after point 2.1.4.:

‘2.1.5. Primary vehicle sub-group ....’;

(o) the following points are inserted after point 2.2.8.:

‘2.2.9. Average gearbox efficiency (%) …...

2.2.10. Average axle efficiency (%) ....’;

(p) the following points are inserted after point 2.3.16.:

‘2.3.17. Fuel and energy consumption of auxiliary heater in case of zero emission vehicle (g/km, g-p-km, l/100km, l/p-km, MJ/km, MJ/p-km) ....

2.3.18. CO_2 of auxiliary heater in case of zero emission vehicle (g/km, g/p-km) ....

2.3.19. Utility factor ....’;

(q) point 2.4. is replaced by the following:

‘2.4. Electric and zero emission ranges (for beginning and end of life)’;

(r) the following point is inserted after point 2.4.3.:

‘2.4.4. Hydrogen range (km) ....’;

(b) Part II is amended as follows:

(a) the following point is inserted after point 1.1.5a.:

‘1.1.5b. Total propulsion power relevant for subgroup allocation ....’;

(b) the following point is inserted after point 1.1.15.:

‘1.1.15a. FCHV architecture (e.g. F2, F3) ....’;

(c) point 1.1.18. is deleted;

(d) the following point is inserted after point 1.1.21.:

‘1.1.22. Vehicle type approval number ....’;

(e) the following point is inserted after point 1.2.18.:

‘1.2.19. Fuel cell system(s) total rated power (kW) ....’;

(f) point 2 is replaced by the following:

‘2. CO_2 emissions and fuel consumption of the vehicle (for each mission profile and loading combination, for OVC-HEVs separately for charge depleting mode, charge sustaining mode and weighted, for OVC-FCHV separately for charge depleting mode and charge sustaining mode)’;

(g) the following points are inserted after point 2.4.5.:

‘2.4.6. Fuel and energy consumption of auxiliary heater in case of zero emission vehicle (g/km, g-p-km, l/100km, l/p-km, MJ/km, MJ/p-km) ....

2.4.7. CO_2 of auxiliary heater in case of zero emission vehicle (g/km, g/p-km) ....

2.4.8. Utility factor ....’;

(h) point 2.5. is replaced by the following:

‘2.5. Electric Ranges (for begin and end of life)’;

(i) the following point is inserted after point 2.5.3.:

‘2.5.4. Hydrogen range (km) ....’;

(j) point 2.6.1. is replaced by the following:

‘2.6.1. Specific CO_2 emissions (g/t-km) ....’;

(k) point 2.6.4. is replaced by the following:

‘2.6.4. Specific CO_2 emissions (g/p-km) ....’;

(l) points 2.6.7., 2.6.8. and 2.6.9. are replaced by the following:

‘2.6.7. Actual charge depleting range for beginning and end of life (km) ....

2.6.8. Equivalent all electric range for beginning and end of life (km) ....

2.6.9. Zero CO_2 emission range for beginning and end of life (km) ....’;

(m) the following points are inserted after point 2.6.9.:

‘2.6.10. Hydrogen range (km) ....

2.6.11. CO_2 (g/km) ....

2.6.12. CO_2 (g/m³-km) ....

2.6.13. Fuel consumption (g/km) ....

2.6.14. Fuel consumption (g/t-km) ....

2.6.15. Fuel consumption (g/p-km) ....

2.6.16. Fuel consumption (g/m3-km) ....

2.6.17. Fuel consumption (l/100km) ....

2.6.18. Fuel consumption (l/t-km) ....

2.6.19. Fuel consumption (l/p-km) ....

2.6.20. Fuel consumption (l/m3-km) ....

2.6.21. Energy consumption (MJ/km, kWh/km) ....

2.6.22. Energy consumption (MJ/t-km) ....

2.6.23. Energy consumption (MJ/p-km) ....

2.6.24. Energy consumption (MJ/m3-km, kWh/m3-km) ....';

(c) in Part III, point 1.1. is replaced by the following:

'1.1. Input data and input information as set out in Annex III for the primary vehicle except: engine fuel map; engine correction factors WHTC_Urban, WHTC_Rural, WHTC_Motorway, BFColdHot, CFRegPer; torque converter characteristics; loss maps for transmission, retarder, angle drive and axle; electric power consumption map(s) for electric motor systems and IEPC; electric loss parameters for REESS; fuel map for FCS'.

ANNEX IV

Annex V is amended as follows:

(1) in point 3.1.2, the following paragraph is added:

'If an engine of the engine CO_2 family, defined in accordance with Appendix 3, is installed in a vehicle equipped with an on-board device for the monitoring and recording of fuel and/or energy consumption and mileage of motor vehicles, in accordance with the requirements referred to in point (b) of Article 5c of Regulation (EC) 595/2009, the test engine shall be equipped with this on-board device.';

(2) in point 3.1.6.2, the heading of the table 'Table 1' is replaced by 'Table 1a';

(3) point 3.2. is amended as follows:

(a) in the first paragraph, the second sentence is replaced by the following:

'The fuel properties of the reference fuels listed in table 1 shall be those specified in Annex IX to Commission Regulation (EU) No 582/2011 and for hydrogen in Annex 5 of UN Regulation No. 49.';

(b) the sixth paragraph is replaced by the following:

'For gas and hydrogen fuels the standards for determining the NCV according to table 1 contain the calculation of the calorific value based on the fuel composition. The gas or hydrogen fuel composition for determining the NCV shall be taken from the analysis of the reference fuel batch used for the certification tests. For the determination of the gas or hydrogen fuel composition used for determining the NCV only one single analysis by a lab independent from the manufacturer applying for certification shall be performed. For gas or hydrogen fuels the NCV shall be determined based on this single analysis instead of a mean value of two separate measurements.’;

(c) the seventh paragraph is replaced by the following:

‘For gas and hydrogen fuels, switches between fuel supply tanks of different production batches are allowed exceptionally. In that case, the NCV of each used fuel batch shall be calculated and the highest of those values shall be documented.’;

(d) in table 1 the following row is added:

‘

Hydrogen / PI or Hydrogen / CI	Hydrogen	ISO 6976 or ASTM 3588

’;

(4) in point 3.2.1, first paragraph, the second sentence is replaced by the following:

‘One of the two reference fuels shall always be B7 and the other reference fuel shall be G25, GR, LPG Fuel B or Hydrogen.’;

(5) in point 3.5., table 2, the row ‘Fuel mass flow for gaseous fuels’ is replaced by the following:

‘

Fuel mass flow for gaseous and hydrogen fuels	≤ 1 % max calibration(3)	0,99 – 1,01	≤ 1 % max calibration 3)	≥ 0,995	1 % of reading or 0,5 % of max. calibration 3) of flow whichever is larger	≤ 2 s

’;

(6) in point 4.3.3.1, the paragraph is replaced by the following:

‘In addition to the provisions defined in Annex 4 to UN Regulation No. 49, the actual fuel mass flow consumed by the engine in accordance with paragraph 3.4 and the data referred to in point 4.3.5.3(5)(a) in application to the WHTC test shall be recorded.’;

(7) in point 4.3.4.1, the paragraph is replaced by the following:

‘In addition to the provisions defined in Annex 4 to UN Regulation No. 49, the actual fuel mass flow consumed by the engine in accordance with paragraph 3.4 and the data referred to in point 4.3.5.3(5)(a) in application to the WHSC test shall be recorded.’;

(8) in point 4.3.5.3, the first paragraph, the following subpoint is added after subpoint (4):

‘(5) If the test engine is equipped with an on-board device for the monitoring and recording of fuel and/or energy consumption and mileage of motor vehicles, according to point 3.1.2:

(a) the information described in points 8.13.15.3 to 8.13.15.8 of Annex Xa;

(b) for each point of the fuel mass flow recorded according to point (3) the OBFCM instantaneous value of the engine fuel rate referred to in point 5.13 of Annex Xa;

(c) the time intervals between the different points of the fuel mass flow recorded according to point (3).';

(9) in point 5.3.3.1., table 4, the following entry is added:

'

Hydrogen / PI or Hydrogen / CI	Hydrogen	120,0

';

(10) in Appendix 2, Part 1, is amended as follows:

(a) point 3.2.2.2 is replaced by the following:

'

3.2.2.2.	Heavy duty vehicles Diesel/Petrol/LPG/NG/Ethanol (ED95)/Ethanol (E85)/ Hydrogen (T) /Hydrogen (TD) /Hydrogen (U) /Hydrogen (UD)[(1)]							

';

(b) point 3.2.17.1 is replaced by the following:

'

3.2.17.1.	Fuel: LPG /NG-H/NG-L /NG-HL/ Hydrogen (T) /Hydrogen (TD) /Hydrogen (U) /Hydrogen (UD)[(1)]							

';

(c) point 3.5.5.2.1 is replaced by the following:

'

3.5.5.2.1.	For dual-fuel engines operated with natural gas or LPG: Specific CO_2 emissions over the WHSC in accordance with point 6.1 of Appendix 4 g/kWh							

';

(d) the following points are inserted after point 3.5.5.2.1:

'

3.5.5.2.2.	For dual-fuel engines operated with hydrogen: Specific energy consumption over the WHSC in accordance with point 6.2 of Appendix 4 MJ/kWh							
3.5.5.2.3.	For dual-fuel engines operated with hydrogen: Specific diesel consumption over the WHSC, $SFC_{WHSC,corr}$, determined in accordance with point 6 of Appendix 4 g/kWh							

’;

(11) Appendix 4 is amended as follows:

(a) point 4 is amended as follows:

(a) the following paragraph is inserted after the second paragraph:

‘If an engine of the engine CO_2 family selected according to point 3 is installed in a vehicle equipped with an on-board device for the monitoring and recording of fuel and/or energy consumption and mileage of motor vehicles, in accordance with the requirements referred to in point (b) of Article 5c of Regulation (EC) 595/2009, the test engine shall be equipped with this on-board device.’;

(b) in the fifth paragraph, subpoint (3) the following paragraph is added:

‘In case market fuel or reference fuel of the type hydrogen is used, the NCV shall be calculated in accordance with the applicable standards as set out in table 1 of this Annex from the fuel analysis submitted by the fuel supplier.’;

(b) in point 5.3, first paragraph, subpoint (b) is amended as follows:

(a) in sub-subpoint E, the first sentence is replaced by the following:

‘For dual-fuel engines operated with natural gas or LPG point D. above shall not apply.’;

(b) the following sub-subpoint is added:

‘F. For dual-fuel engines operated with hydrogen, point D. shall not apply. Instead, the evolution coefficient shall be calculated by dividing the specific energy consumption of the second test by the specific energy consumption of the first test. The two values for specific energy consumption shall be determined in accordance with the provisions set out in point 6.2 of this Appendix using the two values of $SFC_{WHSC,corr}$ determined in accordance with sub-subpoint C. The evolution coefficient may have a value less than one.’;

(c) point 5.4 is replaced by the following:

‘5.4 If the provisions laid down in point 5.3 (b) of this Appendix are applied, the subsequent engines selected for testing of conformity of CO2 emissions and fuel consumption related properties shall not be subjected to the running-in procedure, but their specific fuel consumption over the WHSC or specific CO2 emissions over the WHSC in the case of dual-fuel engines operated with natural gas or LPG or specific energy consumption in the case of dual-fuel engines operated with hydrogen determined on the newly manufactured engine with a maximum run-in time of 15 hours in accordance with point 5.1 of this Appendix shall be multiplied by the evolution coefficient.';

(d) point 5.5 is amended as follows:

(a) the introductory wording is replaced by the following:

'In the case described in point 5.4 of this Appendix the values for the specific fuel consumption over the WHSC or specific CO2 emissions over the WHSC in the case of dual-fuel engines operated with natural gas or LPG or specific energy consumption in the case of dual-fuel engines operated with hydrogen to be taken shall be the following:';

(b) subpoint (b) is replaced by the following:

'(b) for the other engines, the values determined on the newly manufactured engine with a maximum run-in time of 15 hours in accordance with point 5.1 of this Appendix multiplied by the evolution coefficient determined in accordance with point 5.3, subpoint (b), sub-subpoint (D), of this Appendix or point 5.3, subpoint (b), sub-subpoint (E), of this Appendix in the case of dual-fuel engines operated with natural gas or LPG or point 5.3 subpoint (b), sub-subpoint(F), of this Appendix in the case of dual-fuel engines operated with hydrogen.';

(e) in point 5.6, the second sentence is replaced by the following:

'In this case the specific fuel consumption over the WHSC or specific CO2 emissions over the WHSC in the case of dual-fuel engines operated with natural gas or LPG or specific energy consumption in the case of dual-fuel engines operated with hydrogen determined on the newly manufactured engine with a maximum run-in time of 15 hours in accordance with point 5.1 of this Appendix shall be multiplied by the generic evolution coefficient of 0,99.';

(f) in point 6.1 the first paragraph is replaced by the following:

'For dual-fuel engines operated with natural gas or LPG, the target value to assess the conformity of the certified CO_2 emissions and fuel consumption related properties shall be calculated from the two separate values for each fuel of the corrected specific fuel consumption over the WHSC, $SFC_{WHSC,corr}$, in g/kWh determined in accordance with point 5.3.3 of this Annex. Each of the two separate values for each fuel shall be multiplied by the respective CO_2 emission factor for each fuel in accordance with table 1 of this Appendix. The sum of the two resulting values of specific CO_2 emissions over the WHSC defines the applicable target value to assess the conformity of the certified CO_2 emissions and fuel consumption related properties of dual-fuel engines operated with natural gas or LPG.';

(g) the following point is added after point 6.1:

'6.2 Special requirements for dual-fuel engines operated with hydrogen

For dual-fuel engines operated with hydrogen, the target value to assess the conformity of the certified CO_2 emissions and fuel consumption related properties shall be calculated from the two separate values for each fuel of the corrected specific fuel consumption over the WHSC, $SFC_{WHSC,corr}$, in g/kWh determined in accordance with point 5.3.3 of this Annex. Each of the two separate values for each fuel shall be multiplied by the respective NCV_{std}, as set out in point 5.3.3.1, for each fuel shall be multiplied by a factor of 0,001. The sum of the two resulting values of specific energy consumption over the WHSC defines the applicable target value to assess the conformity of the certified CO_2 emissions and fuel consumption related properties of dual-fuel engines operated with hydrogen.';

(h) point 7.6 is replaced by the following:

'7.6 For dual-fuel engines operated with natural gas or LPG point 7.5 shall not apply. Instead, the actual value for assessment of conformity of the certified CO_2 emissions and fuel consumption related properties shall be the sum of the two resulting values of specific CO_2 emissions over the WHSC determined in accordance with the provisions set out in point 6.1 of this Appendix using the two values of $SFC_{WHSC,corr}$ determined in accordance with point 7.4 of this Appendix.';

(i) the following point is added after point 7.6:

'7.7 For dual-fuel engines operated with hydrogen point 7.5 shall not apply. Instead, the actual value for assessment of conformity of the certified CO_2 emissions and fuel consumption related properties shall be the sum of the two resulting values of specific energy consumption over the WHSC determined in accordance with the provisions set out in point 6.2 using the two values of $SFC_{WHSC,corr}$ determined in accordance with point 7.4.';

(j) point 8 is replaced by the following:

'8. Limit for conformity of one single test

For diesel engines, the limit values for the assessment of conformity of one single engine tested shall be the target value determined in accordance with point 6 plus 4 percent.

For engines operated with a single fuel other than diesel and for dual-fuel engines, the limit values for the assessment of conformity of one single engine tested shall be the target value determined in accordance with point 6 plus 5 percent.';

(k) the following point is inserted after point 8:

'8.1 For dual-fuel engines operated with hydrogen an additional limit value regarding the specific diesel consumption over the WHSC, $SFC_{WHSC,corr}$, shall apply. The applicable additional limit value for the assessment of conformity of one single engine tested shall be the specific diesel consumption over the WHSC, $SFC_{WHSC,corr}$, determined in accordance with point 6 plus a tolerance of 4g/kWh.';

(l) in point 9.2 the following paragraph is added:

'Notwithstanding the first paragraph, for dual-fuel engines operated with hydrogen a single test of one engine tested in accordance with point 4 of this Appendix shall also be considered as nonconforming if the actual value of the specific diesel consumption over the WHSC, $SFC_{WHSC,corr}$, determined in accordance with point 7 is higher than the limit values defined in accordance with point 8.1.';

(12) in Appendix 7, table 1a, the row 'FuelType' is replaced by the following:

'

FuelType	P193	string	[-]	Allowed values: "Diesel CI", "Ethanol

				CI", "Petrol PI", "Ethanol PI", "LPG PI", "NG PI", "NG CI", "H2 CI", "H2 PI";

';

ANNEX V

Annex VI is amended as follows:

(1) the point 4.1.7.2 after point 4.2.7.1 is replaced by the following:

'4.2.7.2. Measurement sequence';

(2) the following point is added after point 6.1.2.1:

'6.1.3. Case C: Belt (or similar technology) that is used for connection of an electric machine system to the main powertrain of the vehicle (as defined in the description of the optional ADC input data in table 8 of Annex III of this Regulation).

In this case the input data required in accordance with table 7 of Appendix 12 shall be determined in accordance with the provisions defined in Appendix 11, whereby the value of f_T shall be 0,08 and the maximum available torque of the electric machine system shall be used for $T_{max,in}$.';

(3) in Appendix 9, the second 'Stall point' section is replaced by the following:

'Stall point:

- Torque ratio at stall point v_0=0:

$\mu(v_0)=1{,}8/v_s$';

(4) in Appendix 12, table 1, in row 'DifferentialIncluded', in column 'Description/Reference' the following text is added:

'This input parameter is only required for front wheel driven vehicles.'.

ANNEX VI

'Annex VIIa

Certification procedure for testing wheel ends

1. Introduction and definitions

1.1 Introduction

This Annex describes the certification procedure regarding the friction losses of wheel ends for non-driven axle applications. The certification of wheel ends on driven axles is included in the procedure laid down in Annex VII.

Alternatively to the certification of wheel ends, the standard friction losses of wheel ends as set out in point 6 can be applied for the purpose of the determination of vehicle specific CO_2 emissions.

1.2 Definitions

For the purposes of this Annex the following definitions shall apply:

(1) 'wheel bearing' means the bearings that are used to support one wheel end in a vehicle.

(2) ‘wheel end’ means the assembly of components that establish the connection between the wheel and the axle, which includes the wheel bearings, seals and lubricants as well as the wheel hub, if available, and all other components relevant to the rotational friction, and may exclude the brake disc and wheel flange.

(3) ‘radial load’ means the load applied to the wheel end perpendicular and vertically to the shaft axis.

(4) ‘axial load’ means the load applied to the wheel end in the direction of the shaft axis considering the dynamic wheel radius.

(5) ‘load line position’ means the position on the wheel end through which the radial load is applied.

(6) ‘wheel end manufacturer’ means the legal entity that produces the wheel end.

(7) ‘wheel end family’ means a manufacturer's grouping of wheel ends which through their design, as set out in point 2.3, have similar design characteristics and CO_2 and fuel consumption properties.

(8) ‘customer’ means the legal entity that sells the vehicle or axle in which the wheel end is installed.

(9) ‘testing entity’ means the legal entity responsible for testing the wheel end, either the wheel end manufacturer or a third-party.

(10) ‘seal’ means the part of the wheel bearing designed to prevent the intrusion of particles or liquids in the wheel bearing, or to prevent lubricant leakage.

(11) ‘clearance’ means the total distance through which one bearing ring can be moved relative to the other in the axial direction.

(12) ‘preload’ means the negative operating clearance in the wheel bearing.

(13) ‘inner ring’ means the ring or rings of the wheel bearings with smaller diameter than the outer ring.

(14) ‘outer ring’ means the ring or rings of the wheel bearings with greater diameter than the inner ring.

(15) ‘measurement’ means the measurement of friction losses in the wheel end expressed as a friction torque in Nm.

(16) ‘bearing rated load’ means the maximum design load as defined in the wheel bearing specifications.

(17) ‘pitch diameter’ means the distance in a wheel bearing between the geometrical centre of two rolling elements when the two rolling elements are diametrically opposed.

(18) ‘run-in procedure’ means the procedure of conditioning an unused wheel end under load in order to bring it to a state of representative in-use conditions.

2. General requirements

2.1 Wheel end selection

The wheel ends used for the verification of friction loss measurements shall be new.

They shall be the same wheel ends as defined by specifications, as intended for series production, and as will be installed in the customer’s applications.

These specifications include, but are not limited to, the dimensions, the materials, the surfaces' quality and treatments, the numbers of rollers, the seal, the lubricant's type, quality, and quantity as well as any other characteristic relevant for the friction of the wheel end.

2.2 Number of wheel ends to test

For the purpose of the CO_2 certification of a wheel end family, at least four different wheel ends from the family parent shall be tested according to the procedures described in points 3. and 4. using for each the same speed and load target steps.

2.3 Parameters defining a wheel end family

The following criteria shall be the same to all members of a wheel end family:

- rolling elements' quantity;
- rolling elements' diameter within ± 0,5mm (when measured perpendicular and at the centre of the long axis);
- rolling elements' length within ± 1mm (when measured along the long axis);
- pitch diameter within ±1mm;
- number of rows;
- outer ring contact angle with the rolling elements with ± 1deg;
- the lubricant type: oil or grease;
- load-line position (in the case the family parent is not tested at the indicated position in Figure 2).

2.4 Choice of the wheel end family parent

The family parent of a wheel end family shall be the member with the highest friction.

If a family has more than one member, the testing entity shall justify the choice of the family parent based on separate component properties.

The bearing rated load for the family shall be the highest bearing rated load of all family members.

For each family member, the testing entity shall provide quantifiable data on:

- the seals performance (e.g. friction losses);
- the lubrication (oil or grease) performance (e.g. viscosity);
- the preload / clearance range (e.g. maximum and minimum).

When the approval authority considers that the properties listed in the fourth paragraph are sufficient to justify the choice of the family, it may request the testing entity to provide additional justification, including by means of simulations or calculations.

2.5 Run-in

The testing entity shall apply a run-in procedure on the wheel ends.

The run-in procedure shall use the same test set up and have the same requirements as for the measurements of friction losses.

2.5.1 Run-in procedure

The run-in procedure shall comprise of four successive phases.

During the first phase, the wheel end shall be run clockwise at a constant speed of 300 rpm with a radial load applied corresponding to 50% of the bearing rated load for a duration of 60 ±2 minutes.

During the second phase, the wheel end shall be run counterclockwise at a constant speed of 300 rpm with a radial load applied corresponding to 50% of the bearing rated load for a duration of 60 ±2 minutes.

During the third phase, the wheel end shall be run clockwise at a constant speed of 500 rpm with a radial load applied corresponding to 100% of the bearing rated load for a duration of 660 ±2 minutes.

During the fourth phase, the wheel end shall be run counterclockwise at a constant speed of 500 rpm with a radial load applied corresponding to 100% of the bearing rated load for a duration of 660 ±2 minutes.

The run-in procedure shall be documented by the testing entity with regard to run-time, speed, radial load, and bearing temperature, and reported to the approval authority.

2.6 Lubricant

2.6.1 Lubricant requirements

The lubricant type, quality and quantity shall be the same as defined by specifications, as intended for series production, and as will be installed in customer’s applications.

If the wheel end manufacturer is not delivering lubricant with the wheel bearing, the customer shall provide the necessary information on the lubricant that will be used in the final application to allow accurate testing of the wheel end.

2.6.2 Oil lubricant

If the lubricant is of the oil type, the oil level within the bearing shall be as defined in the axle specifications. In the absence of a specification the maximum geometrically possible oil level of the axle shall be applied.

2.7 Operating clearance/Preload

If the bearing operating clearance/preload can be adjusted, the clearance/preload used for testing the wheel bearing shall be set at the arithmetic mean of the clearance/preload range defined in the specifications, within a tolerance of ±20 µm.

2.8 Seals

The seals used for testing the wheel end shall be the same as defined by the specifications, as intended for series production, and as will be installed in the customer’s applications.

If the wheel end manufacturer is not delivering seals with the wheel end, the customer shall provide the necessary information on the seals that will be used in the final application to allow accurate testing of the wheel end.

3. Testing procedure for wheel ends

3.1 Test conditions

3.1.1 Ambient temperature

The temperature in the test cell shall be maintained at 25 °C ± 10 °C. The ambient temperature shall be measured within a distance of 1 meter to the wheel bearing’s outer ring and documented in the test report. It shall be a target temperature for the testing entity, of which systematic deviations across tests are not allowed.

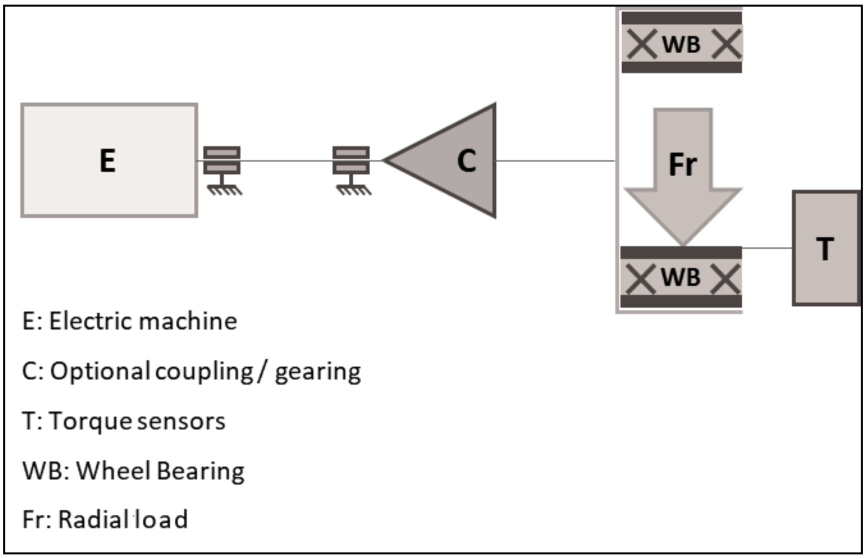
3.1.2 Wheel bearing temperature

The wheel bearing temperature shall be measured on the bore-side of the inner ring located on the inner-side of the vehicle. During measurements, the wheel bearing temperature shall be kept at a maximum of 60°C. For that purpose, air cooling may be applied in accordance with section 3.3.5.

3.2 Test set-up

The test set-up shall be as illustrated in Figure 1.

Figure 1. Simplified schematic of the test set-up



3.2.1 Installation of torque, load, temperature, and speed measuring devices

Torque measuring devices shall be installed in order to measure friction losses in the wheel end, and in such a way that parasitic effects are minimized.

A speed measuring device shall be installed to measure the rotational speed of the wheel end.

A temperature measuring device shall be installed to measure the temperature of the bore-side of the inner ring on the inner-side of the vehicle.

A load measuring device shall be installed to measure the radial load applied on the wheel end.

3.2.2 Test set-up

The test set-up shall consist of an electric machine used to apply a rotational speed to the wheel end, and of a device capable of applying a radial load onto the wheel end.

The wheel end shall be installed such that the outer ring of the wheel bearing is rotating and used for speed input, while the inner ring is not rotating.

Gearings and couplings are allowed between the electric machine and the wheel end, provided that they do not influence the results of the measurements.

3.2.3 Measurement equipment

The calibration laboratory facilities shall comply with the requirements of either IATF 16949, ISO 9000 series or ISO/IEC 17025. All laboratory reference measurement equipment, used for calibration and/or verification, shall be traceable to national (international) standards.

The measurement accuracies set in points 3.2.3.1 to 3.2.3.4 shall concern the complete measurement chain, including sensors and additional sources of inaccuracy. The specified tolerances for uncertainty shall not be used for systematic deviations when measurement instruments are applied with higher accuracy.

3.2.3.1 Friction torque

The uncertainty of the torque measurement for the measurement of the wheel end's friction torque shall not exceed ± 0,2 Nm.

In the case of a higher uncertainty, the measurements shall be calculated as set out in point 3.4.6.

3.2.3.2 Radial load

The uncertainty of the load measurement for the measurement of radial load applied on the wheel end shall not exceed ± 1 kN.

If the radial load is applied as a mass, this shall be converted by applying the gravitational constant of 9.81 N/kg.

3.2.3.3 Rotational speed

The uncertainty of the rotational speed measurement for the measurement of the wheel end speed shall not exceed ± 2,5 rpm.

3.2.3.4 Temperatures

The uncertainty of the temperature measurement for the measurement of the ambient temperature shall not exceed ± 2 °C.

The uncertainty of the temperature measurement for the measurement of wheel bearing temperature shall not exceed ± 2 °C.

3.2.4 Measurement signals and data recording

The following signals shall be recorded for the purpose of the calculation of the friction torque losses:

(a) Input rotational speed [rpm]

(b) Wheel end friction torque [Nm]

(c) Applied radial load [kN]

(d) Bearing temperature [°C]

(e) Ambient temperature [°C]

The following minimum sampling frequencies of the sensors shall be applied:

(a) Friction torque: 300 Hz

(b) Rotational speed: 100 Hz

(c) Temperatures: 10 Hz

(d) Load: 10 Hz

The raw data of the friction torque shall be filtered by a suitable low-pass filter such as a Butterworth 2nd order filter with a cut-off frequency of 0.1 Hz. Filtering of the other signals may be applied in agreement with the approval authority. Any aliasing effect shall be avoided.

The raw data shall not be reported.

3.3 Test procedure

To determine the torque loss map for a wheel end, the grid points of the friction torque loss map data shall be measured as specified in point 3.4.

The measurement of a grid point may only be repeated if there is a technical justified reason to do so such as the failure of a measurement sensor. This repetition shall be recorded in the test report. The total testing of one wheel end sample, from initiating the run-in until concluding the last grid point, shall be concluded within a maximum of 55 hours, otherwise the test of the sample will be void.

3.3.1 Radial load range

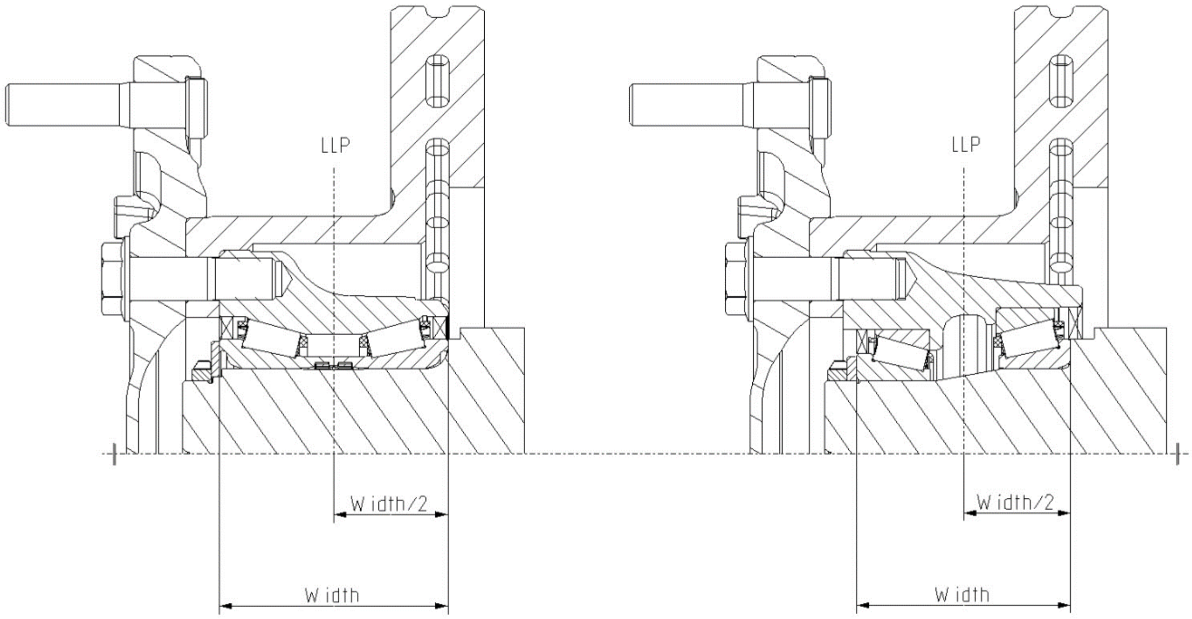
The friction loss map shall be measured with radial loads corresponding to 25%, 50%, and 100% of the bearing rated load.

The target loads shall be reported by the testing entity together with the actual measured load.

3.3.2 Radial load line position

The radial load shall be applied onto the wheel end at its centre, so that the load line position is at the centre of the wheel bearing within ± 0,5 mm. The centre of the wheel bearing is determined as the middle of the outside positions of the inner WB rings (see Figure 2).

Figure 2 – Determination of Load Line Position



At the request of the manufacturer and with the approval of the approval authority the load line position may be chosen outside the centre of the bearing. In this case the manufacturer has to provide evidence that this load line position corresponds to the application of the wheel end.

3.3.3 Axial load

For the purpose of these the measurements set out under this point, no axial load shall be applied onto the wheel ends.

3.3.4 Rotational speed range

The wheel end shall be tested at 250 and 500 rpm. All rotational speed points shall be measured in a clockwise and counterclockwise direction in accordance with the testing sequence specified in point 3.4.1. The results may be reported as the average measured values of the clockwise and counterclockwise direction.

3.3.5 Cooling and heating

The wheel end may be air cooled by a fan using ambient air at ambient temperature as defined in 0. Other external cooling or heating shall not be allowed. In the case that air cooling is used, the same cooling condition shall be applied for all tested wheel ends at all grid points.

3.4 Measurement of friction torque loss maps

3.4.1 Testing sequence

The testing sequence to be applied depends on the measurement configuration of the test set-up.

In the case that the measurement configuration is such that the radial load and the friction torque are both determined individually by dedicated torque measurement device, the wheel end testing shall follow Testing sequence A as described in point 3.4.1.1.

In the case that the measurement configuration is such that the radial load and the friction torque are determined simultaneously by the same torque measurement device, the wheel end testing shall follow Testing sequence B as described in point 3.4.1.2.

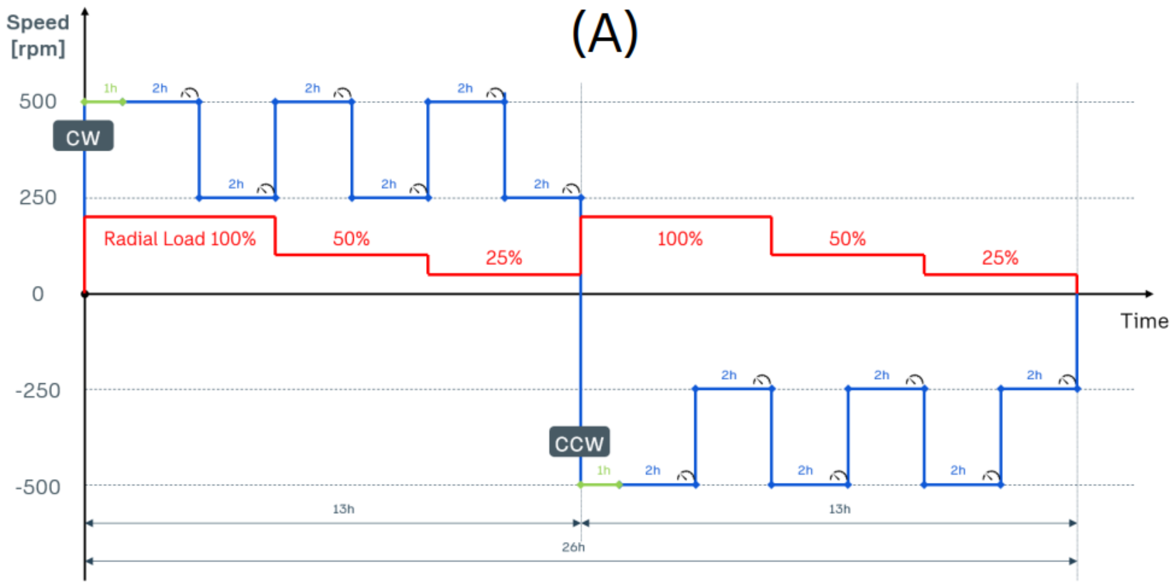
If, based upon the functional descriptions referred to in the first and second paragraphs, the testing entity cannot judge which test sequence shall be used, Testing sequence A shall be applied.

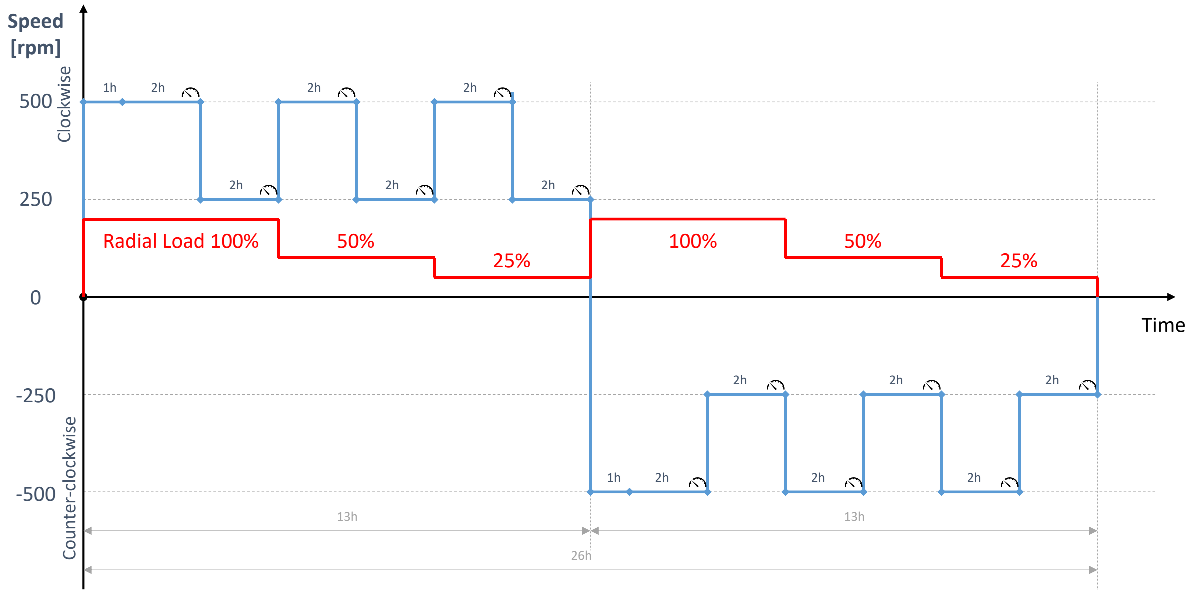
3.4.1.1 Testing sequence A

The friction measurements of the grid points shall start at the highest radial load downwards to the lowest radial load, while at each load step first the highest and then the lowest rotational speed shall be tested. Once the grid point at the lowest load and lowest rotational speed has been measured, the rotational direction on the wheel end is reversed and the previously described sequence is repeated.

The testing sequence is shown schematically in Figure 3.

Figure 3 – Testing sequence scheme A





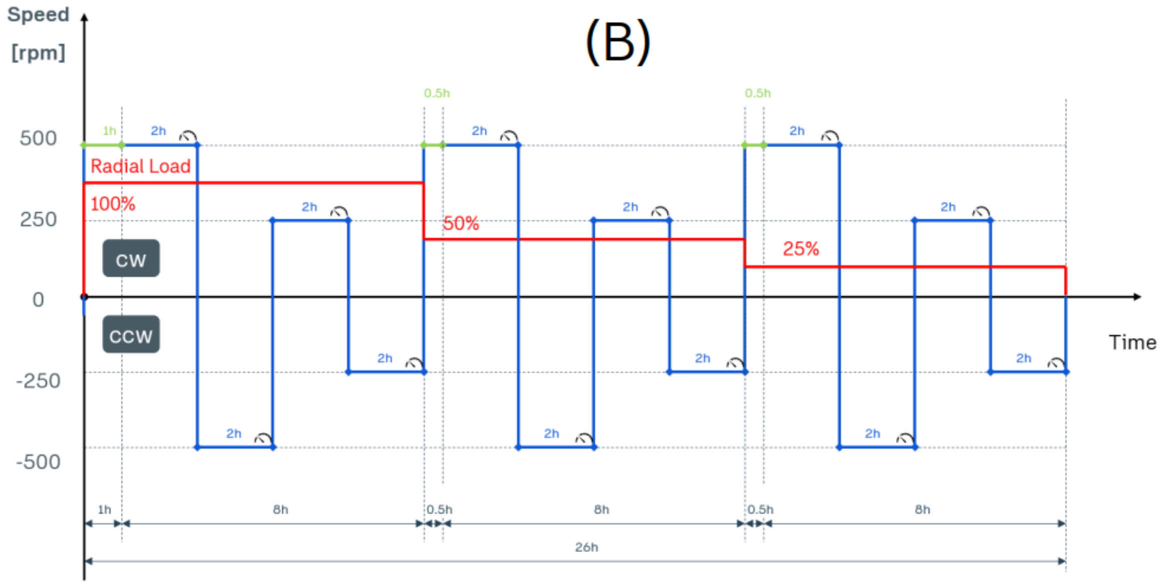
3.4.1.2 Testing sequence B

The friction measurements of the grid points shall start at the highest radial load and the highest rotational speed. Then the rotational direction is reversed and then the same load/speed point is measured. While keeping the same load, the rotational direction is again reversed and the friction is measured at the lower rotational speed. This load/speed point is also measured in both rotational directions. The previously described sequence is repeated for the 50% and 25% radial load settings.

The testing sequence is shown schematically in Figure 4.

Figure 4

Testing sequence scheme B



3.4.2 Stabilisation and measurement duration

For each grid point the testing entity shall allow for a stabilisation period of 117±2 minutes before starting the measurement. In addition, the following stabilisation periods shall be applied:

- For Testing sequence A:
  Before the first grid point and before the seventh grid point (after the rotational direction has been reversed) the stabilisation period shall be extended by an additional 60±2 minutes. The stabilisation times are indicated in Figure 3.
- For Testing sequence B:
  Before the first grid point the stabilisation period shall be extended by an additional 60±2 minutes. Before the fifth and the nineth grid point the stabilisation period shall be extended by an additional 30±2 minutes. The stabilisation times are indicated in Figure 4.

The friction for each single grid point shall be measured during the last 180 seconds of the corresponding constant speed phase. In the case that the stabilisation criterion as described in section 3.4.3 is not fulfilled during the last 180 seconds of the grid point, the measurement may be taken from the first earlier uninterrupted segment of 180 seconds where the stabilisation criterion was fulfilled.

In the case that the test set-up is equipped with a support of the wheel end by means of a support bearing, which is required to be rotated in both directions during the measurement of each grid point, the friction shall be measured during the last 180 seconds of the clockwise rotation of the support bearing and during the last 180 seconds of the counterclockwise rotation of the support bearing.

3.4.3 Stabilisation criterion

The stabilisation criterion shall be met when the standard deviation of friction torque during measurement does not exceed 15 % of the mean value or 0.4 Nm, whichever value is the highest.

3.4.4 Averaging of grid points

For every individual sample, all recorded values for each grid point shall be averaged to an arithmetic mean over the measurement duration. Next, these arithmetic mean values of the same grid point shall be averaged over all samples to one arithmetic mean value per grid point.

3.4.5 Measurement validation

For each grid point:

- The wheel end speed value before averaging shall not deviate from the set value by more than ± 5 rpm;
- The radial load value before averaging shall not deviate from the set value by more than ± 2 kN;
- No systematic deviation from the set values is allowed.

If the above specified criteria are not met, the measurement of the respective grid point is void. In this case, the measurement for the entire affected speed and load step shall be repeated, and the reason for voiding the grid point shall be recorded in the test report. After passing the repeated measurement, the data shall be consolidated.

3.4.6 Assessment of total uncertainty of the torque loss

In the case that the uncertainties on the measured friction torque are below the limit set in point 3.2.3.1, the reported friction torque loss shall be regarded as equal to the measured friction torque losses.

In the case of higher uncertainties, the part of the uncertainty exceeding the limit shall be added to the measured friction torque losses.

The final wheel end friction torque loss at a given speed and load shall thus be calculated as follows:

$$\mathrm{T}_{\mathrm{reported}} = \mathrm{T}_{\mathrm{measured}} + \max(0, \mathrm{U}_{\mathrm{t}} - \mathrm{U}_{\mathrm{limit}})$$

Where:

- $T_{reported}$ is the calculated friction torque loss at a given speed and load reported for the CO_2 certification of wheel ends [Nm];
- $T_{measured}$ is the measured friction torque loss according to section 3.4.4 at a given speed and load [Nm];
- U_t is the absolute value of the torque uncertainty (>0), expressed in Nm;
- U_{limit} is 0.2 Nm.

3.5 Calculation of the friction value for certification

For the calculation of the final friction value for the wheel end, the grid points of the reported torque loss map shall first be averaged for all the wheel end samples in accordance with section 0, corrected in accordance with section 3.4.6, if applicable, and then weighted according to table 1 for non-driven axle wheel end applications.

Table 1

Weighting factors for non-driven axle applications

	250 rpm	500 rpm
25% load	0,4%	2,4%

50% load	7,9%	35,3%
100% load	9,5%	44,5%

3.6 Declaration of the certified friction value

The wheel end manufacturer may declare the weighted average friction as calculated in section 3.5 as the certified value for the wheel end family. Alternatively, the wheel end manufacturer has the option to declare any higher friction value. The declared friction value shall be rounded to 1 place to the right of the decimal point.

4. Conformity of the certified CO_2 emissions and fuel related properties

Every wheel end certified in accordance with this Annex shall be so manufactured as to conform, with regard to the description as given in the certification form and its annexes, to the approved type. The conformity of the certified CO_2 emissions and fuel consumption related properties procedures shall comply with those set out in Article 31 of Regulation (EU) 2018/858.

Conformity of the certified CO_2 emissions and fuel consumption related properties shall be checked on the basis of the description in the certificate set out in Appendix 1 and the specific conditions laid down in this point.

The wheel end manufacturer shall test, at least every second year from the date of the family parent's certification, the number of wheel end families shown in Table 2. The number of wheel end families to be tested depends on the production volumes of the year previous to the year when the conformity of production testing is due.

At least two wheel ends of the same family member shall be tested.

Table 2

Sample size for conformity testing

Production number	Number of wheel end families to be tested
0 – 100 000	2
100 001 – 150 000	3
150 001 – 250 000	4
250 001 and more	5

5. Production conformity testing

For conformity of the certified CO_2 emissions and fuel consumption related properties testing, the wheel end manufacturer shall apply the same procedure as described in point 3, including the run-in procedure and validation criteria.

5.1 Conformity of the certified CO_2 emissions and fuel consumption related properties test assessment

A conformity of the certified CO_2 emissions and fuel consumption related properties test is passed when the weighted average friction value from the conformity testing is lower or equal to the declared friction value for wheel end family, with an allowed tolerance margin of +10%.

If the production conformity testing is not passed, three additional wheel ends shall be tested using the same procedure. The recorded values of all tested ends, including the three additional wheel ends, shall be averaged for each grid point to an arithmetic mean. If the conformity of production test is again not passed, the provisions set out in Article 23 shall apply.

If a family member proves to have higher friction than the family parent, the family member shall be reclassified into another wheel end family, and require a new certification.

6. Standard friction torque loss

The standard friction loss for non-driven axle applications shall be 4,8 Nm.

Appendix 1

MODEL OF A CERTIFICATE OF A COMPONENT, SEPARATE TECHNICAL UNIT OR SYSTEM

Maximum format: A4 (210 × 297 mm)

CERTIFICATE ON CO_2 EMISSIONS AND FUEL CONSUMPTION RELATED PROPERTIES OF A WHEEL END FAMILY

Communication concerning: – granting[1] – extension – refusal[1] – withdrawal[1]	Administration stamp

of a certificate on CO_2 emission and fuel consumption related properties of a wheel end family in accordance with Commission Regulation (EU) 2017/2400. Commission Regulation (EU) 2017/2400 as last amended by ……………………………

Certification number:

Hash:

Reason for extension:

[1] Delete where not applicable

SECTION I

1. Make (trade name of manufacturer):

2. Type:

3. Name and address of manufacturer:

4.Name(s) and address(es) of assembly plant(s):

5. Name and address of the manufacturer's representative (if any)

SECTION II

1. Additional information (where applicable): see Addendum

2. Approval authority responsible for carrying out the tests:

3. Date of test report

4. Number of test report

5. Remarks (if any): see Addendum

6. Place

7. Date

8. Signature

Attachments:

1. Information document

2. Test report

Appendix 2

WHEEL END INFORMATION DOCUMENT

Information document no.: …

Issue: …

Date of issue: …

Date of Amendment: …

pursuant to …

Wheel end type and family (if applicable): …

GENERAL

1. Name and address of manufacturer:

2. Make (trade name of manufacturer):

3. Wheel end type:

4. Axle type:

5. Wheel end family (if applicable):

6. Commercial name(s) (if available):

7. Name(s) and address(es) of assembly plant(s):

8. Name and address of the manufacturer's representative:

PART 1

ESSENTIAL CHARACTERISTICS OF THE (PARENT) WHEEL END AND THE WHEEL END TYPES WITHIN A WHEEL END FAMILY

Specific wheel end characteristics	**Parent wheel end**	**Family member**		
		#1	**#2**	**#3**
Rolling elements' quantity	…	…	…	…
Rolling elements' diameter	…	…	…	…
Rolling elements' length	…	…	…	…
Pitch diameter	…	…	…	…
Number of rows	…	…	…	…
Outer ring contact angle with the rolling elements	…	…	…	…
Lubricant type	…	…	…	…
Load-line position	…	…	…	…
Rated load	…	…	…	…

LIST OF ATTACHMENTS

No.	Description	Date of issue
1	Seal performance	…
2	Lubrication performance	…
3	Preload or clearance range	…
4	List of part numbers for wheel end components	…'.

<u>ANNEX VII</u>

Annex VIII is amended as follows:

(5) in point 2, the following subpoint is added:

'(18) 'CFD' means computational fluid dynamic simulation.';

(6) point 3 is replaced by the following:

'3. Determination of air drag

3.0.1. The constant speed test procedure as set out in points 3.1 to 3.7 shall be applied to determine the air drag characteristics. During the constant speed test, the main measurement signals driving torque, vehicle speed, air flow velocity and yaw angle shall be measured at two different constant vehicle speeds (low and high speed) under defined conditions on a test track. The measurement data recorded during the constant speed test shall be processed in accordance with point 3.8 and entered into the air drag pre-processing tool in accordance with point 3.9 which determines product of drag coefficient by cross sectional area for zero crosswind conditions $C_d{\cdot}A_{cr}$ (0). The criteria that shall be met during the constant speed test procedure to obtain valid results are described in point 3.10.

3.0.2. For vehicles other than the parent vehicle of an air drag family, air drag characteristics may also be determined by combining the $C_d{\cdot}A_{cr}$ (0) from a constant speed test with an incremental difference $\Delta C_d{\cdot}A_{cr}(0)$ CFD obtained by means of CFD. For this purpose, the following requirements shall be met:

(a) the applied CFD method shall be approved in accordance with Appendix 10. For all subsequent applications of the approved CFD method, the boundary conditions set out in point 1., subpoint i,. of subpoint (c) of Appendix 10 shall be complied with;

(b) the application shall only be carried out for vehicles in which the vehicle configuration tested with a constant speed test and the vehicle configuration as analysed using CFD are permitted to be within the same air drag family as set out in point 4 of Appendix 5 for medium and heavy lorries and point 6 of Appendix 5 for heavy buses. The special cases as set out in point 2 of Appendix 5 shall also be taken into account;

(c) the application of CFD shall be limited to positive values of $\Delta C_d{\cdot}A_{cr}(0)_{CFD}$;

(d) a $C_d{\cdot}A_{cr}$ (0) value generated using CFD shall not be higher than the highest value certified exclusively by constant speed test and.

3.0.3. The applicant for a certificate shall declare a value $C_d{\cdot}A_{declared}$ in a range from equal up to a maximum of + 0,2 m^2 higher than the air drag characteristics determined in accordance with points 3.0.1 and 3.0.2, if applicable.
This tolerance shall take into account uncertainties in the selection of the parent vehicles as the worst case for all testable members of the family. The value $C_d{\cdot}A_{declared}$ shall be the input for the simulation tool and the reference value for conformity of the certified CO2 emissions and fuel consumption related properties testing.

Several declared values $C_d{\cdot}A_{declared}$ can be created based on a single measured $C_d{\cdot}A_{cr}$ (0) as long as the family provisions in accordance with point 3.14 of Appendix 5 for medium and heavy lorries and with point 4.16 of Appendix 5 for heavy buses are fulfilled.

3.0.4. Vehicles which are not member of a family shall use the standard values for $C_d{\cdot}A_{declared}$ as described in Appendix 7. In this case no input data on air drag shall be provided. The allocation of standard values shall be done automatically by the simulation tool.';

(7) point 3.2.2., the first sentence is replaced by the following:

'3.2.2. The ambient temperature shall be in the range of 5 °C to 25 °C.';

(8) in point 3.2.5., subpoints (i) and (ii) are replaced by the following:

'i. Average wind speed: ≤ 4 m/s

ii. Gust wind speed (1s central moving average): ≤ 7 m/s';

(9) point 3.3.1.7. is replaced by the following:

‘3.3.1.7. Aftermarket parts which are not covered by the vehicle type approval in accordance with Regulation (EU) 2018/858 (e.g. sun visors, horns, additional head lights, signal lights, bull bars or ski-boxes) are not considered for the air drag in accordance with this Annex.’;

(10) the following point is inserted after point 3.3.1.8.:

‘3.3.1.9. Vehicle equipment designed for the purpose of dynamic charging as defined in point 3(38) of Annex III shall be set in the ‘retracted’ state if both ‘extended’ and ‘retracted’ states are possible.’;

(11) point 3.5.2. is replaced by the following:

‘3.5.2. The average speed within a measurement section in the high speed test shall be in the following range:

maximum speed: 92 km/h for medium and heavy lorries and 102 km/h for heavy buses;

minimum speed: 88 km/h for medium and heavy lorries and 98 km/h for heavy buses. If the vehicle cannot be operated at such speed on the test track, the minimum speed shall be equal to 3 km/h less than the maximum vehicle speed the vehicle can be operated at the test track.’;

(12) in point 3.5.3.1., subpoint (vii), the second indent is replaced by the following:

‘- Heavy buses and medium lorries: the maximum height of the vehicle shall be measured in accordance with the technical requirements of Regulation (EU) 2021/535, by not taking into account the devices and equipment referred to in Appendix 1.’;

(13) in point 3.5.3.3., the following paragraph is added:

‘After the zeroing of the torque meters, any usage of the mechanical service brake invalidates the whole test.’;

(14) point 3.5.3.5. is amended as follows:

(a) subpoint vii. is replaced by the following:

‘vii. the maximum time for the low speed test shall not exceed 25 minutes in order to prevent cool down of the tires’;

(b) subpoint viii. is deleted;

(15) point 3.5.3.8. is replaced by the following:

‘3.5.3.8. Second low speed test

Perform the second measurement at the low speed directly after the high speed test.

The same provisions as for the first low speed test shall be fulfilled.’;

(16) point 3.11. is deleted;

(17) in Appendix 1, Section II, the last paragraph ‘Information package. Test report.’ is replaced by the following:

‘- Test reports from constant speed tests.

- For air drag types generated using a CFD method:

- Images of the vehicle focusing on the areas that are different with respect to the vehicle tested by constant speed test;

- Raw data of the evolution of $C_D{\cdot}A_{cr}$ (0) $_{CFD}$ versus iteration (for steady-state methods) or versus time (for transient methods).’;

(18) in Appendix 2, Part I, the following section is added: Attachment 2 to Information Document

‘*Information on the application of the CFD method (if applicable)*

1.1. CFD method licence number

1.2. Incremental difference $\Delta C_d{\cdot}A_{cr}$ (0) $_{CFD}$ as obtained by CFD’;

(19) in Appendix 5, point 1third sentence is replaced by the following:

‘The manufacturer may decide which vehicles belong to an air drag family as long as the membership criteria listed in point 4 for medium lorries, heavy lorries and point 6 for heavy buses are respected. The air drag family shall be approved by the approval authority.’;

(20) Appendix 6 is amended as follows:

(a) in point 1, subpoint ii. is deleted;

(b) in point 2 the following paragraph is added:

‘Notwithstanding the second paragraph, where the measured C_d A_{cr} *(0)* value of all tests performed in accordance with point 3.1 is higher than the $C_d{\cdot}A_{declared}$ value declared for the parent vehicle plus 7,5 % tolerance margin, Article 23 of this Regulation shall apply to all air drag types set out on the basis of the approved CFD method.’;

(c) the following point is inserted after point 3:

‘3.1 Notwithstanding point 3, if the vehicle manufacturer has been using an approved CFD method for the purpose of determining air drag characteristics in accordance with point 3.0.2. of this Annex, additional vehicles shall also be tested for conformity with the certified CO_2 emissions and fuel consumption related properties in accordance with Table 17a.

Table 17a		
Number of vehicles to be tested for conformity with the certified CO_2 emissions and fuel consumption related properties per year of production for the usage of the CFD method		
Number of CoP tested vehicles	Schedule	Number of vehicles produced for which air drag characteristics have been certified with the use of the approved CFD method

1	every 2nd year	≤ 1000
1	every year	1000 < X ≤ 5000
2	every year	5000 < X ≤ 15000
3	every year	15000 < X ≤ 25000
4	every year	25000 < X ≤ 50000
5	every year	50001 and more

';

(d) in point 4.6, the first sentence is replaced by the following:

'For the tests referred to in point 3, the first vehicle to be tested for conformity with the certified CO_2 emissions and fuel consumption related properties shall be selected from the air drag type or air drag family representing the highest production numbers in the corresponding year.';

(e) the following point is inserted after point 4.6:

'4.7. For the tests referred to in point 3.1, only vehicles for which air drag characteristics have been determined with an approved CFD method shall be selected.';

(21) in Appendix 9, table 1 is amended as follows:

(a) the following rows are inserted after the row 'CdxA_0':

'

DeltaCdxA_CFD	PXXX	double, 2	[m²]	Incremental difference $\Delta C_d \cdot A_{cr, CFD}$ (0) obtained by means of CFD as determined based on point 3.0.2 Only relevant if CFD option is applied
Licence number CFD method	PXXX	token	[-]	Only relevant if CFD option is applied
DeltaCdxA_declared	PXXX	double, 2	[m²]	Difference between $C_d \cdot A_{declared}$ in accordance with point

				3.0.3 and $\Delta C_d \cdot A_{cr}(0)$ in accordance with point 3.0.1 or point 3.0.2, as the case may be.

’;

(1) the row ‘TransferredCdxA’ is replaced by the following:

‘

DeltaTransferredCdxA	PXXX	double, 2	[m²]	Delta CdxAfrom transfer to related families in other vehicle groups in accordance with Table 16 of Appendix 5 for heavy lorries, Table 16a of Appendix 5 for medium lorries and Table 16b of Appendix 5 for heavy buses. In case no transfer rule was applied CdxA_0 shall be provided. In the case of transfers by copying CdxA values from other vehicle groups, "0" shall be provided. If no transfer rule has been applied, leave

				empty.

';

(a) the row 'DeclaredCdxA' is deleted;

(2) the following Appendices are added after Appendix 9:

'*Appendix 10*

Approval of the CFD method

1. For the determination of air drag characteristics using a CFD method as described in point 3.0.2, the validity of the CFD method shall be approved as described below.

   (a) The application of the CFD method shall be in accordance with Appendix 1 of Annex VIII to Regulation (EU) 2018/858.

   (b) The specific validation using physical tests shall be carried out based on two different vehicles "A" and "B", of which B is the vehicle configuration with the lower air drag. A and B shall fulfil the following conditions:

      (i) A and B shall be within the same air drag family as set out in point 4 of Appendix 5 for medium and heavy lorries and point 6 of Appendix 5 for heavy buses. The special cases as set out in point 2 of Appendix 5 shall also be taken into account.

      (ii) The difference in air drag between the two vehicles shall meet the following criterion:

$$\Delta C_d \cdot A_{cr}(0)_{CST} > 3{,}5\% \cdot \frac{C_d \cdot A_{cr}(0)_{CST,avg,A} + C_d \cdot A_{Cr}(0)_{CST,avg,B}}{2}$$

where:

$$\Delta C_d \cdot A_{cr}(0)_{CST} = C_d \cdot A_{cr}(0)_{CST,avg,A} - C_d \cdot A_{Cr}(0)_{CST,avg,B}$$

$C_d \cdot A_{cr}(0)_{CST,avg,A}$	Average value of the air drag values of vehicle A measured in a series of constant speed tests according to the provisions in point 1(d).
$C_d \cdot A_{cr}(0)_{CST,avg,B}$	Average value of the air drag values of vehicle B measured in a series of constant speed tests according to the provisions in point 1(d).

   (c) The manufacturer shall perform the following steps to determine the difference in air drag between A and B using CFD.

      (i) The following conditions shall be met in CFD simulations:

         (1) the vehicle geometries used in the CFD simulations shall correspond to the vehicle setup prescribed in point 3.3 for the constant speed test;

         (2) The air speed in the simulation shall be 90 km/h for lorries and 100 km/h for buses.

(3) Only 0° yaw angle shall be considered.

(4) All wheels (tyres and rims) shall be modelled as rotating elements with the corresponding rotational speed.

(5) The ground of the simulation domain shall be modelled with a tangential velocity opposite to the vehicle advancing direction.

(6) The simulation domain shall be discretised with a minimum of 60 million volume elements, including the corresponding mesh refinements at wake regions and other key aerodynamic areas.

(7) In the case of using steady-state CFD methods, the simulation shall run for a minimum of 2000 iterations.

(8) In the case of using transient CFD methods, the simulations shall run for a minimum of 10 seconds of simulation time.

(9) Deformable parts under aerodynamic loads shall be modelled as per their shape in vehicle operating condition.

(ii) The incremental difference $\Delta C_d \cdot A_{cr}$ (0) $_{CFD}$ between vehicles A and B using the CFD method shall be calculated as:

$$\Delta C_d \cdot A_{cr}\,(0)_{\,CFD} = C_d \cdot A_{cr}\,(0)_{\,CFD,\,A} - C_d \cdot A_{cr}\,(0)_{\,CFD,\,B}$$

where $C_d \cdot A_{cr}$ (0) $_{CFD}$ corresponds to the average of:

- the last, at least, 400 iterations in the case of steady-state methods
- the last, at least, 5 seconds of simulation time in the case of transient methods.

(iii) The $\Delta C_d \cdot A_{cr}$ (0) $_{CFD}$ value shall be submitted to the approval authority before starting the constant speed tests as set out in point (d).

(d) For both vehicle A and B a reference value for the air drag characteristics, respectively $C_d \cdot A_{cr}$ (0) $_{CST,avg,A}$ and $C_d \cdot A_{cr}$ (0) $_{CST,avg,B}$ shall be determined on the basis of a series of constant speed tests. For this purpose, the following points shall be considered:

(i) The reference value for $C_d \cdot A_{cr}$ (0) $_{CST,avg}$ shall be calculated as the arithmetic mean of the $C_d \cdot A_{cr}$ (0) $_{CST}$ values from all available constant speed tests performed with a given vehicle. Only valid results in accordance with point 3.10. shall be taken into consideration. It is not permitted to exclude available and valid constant speed test results for the vehicle configuration under consideration from the evaluation unless this can be justified to the approval authority.

(ii) The 95% confidence interval (CI_{95}) of the mean of test data, $C_d \cdot A_{cr}$ (0) $_{CST,avg}$, shall fall within the range $C_d \cdot A_{cr}$ (0) $_{CST,avg}$ ± 2,5% ,which is determined by the following expression:

$$\left(\frac{s}{\sqrt{n}}\right) \cdot t \leq 0{,}025 \cdot \bar{x}$$

Where:

s is the standard deviation of the sample for $C_d \cdot A_{cr}$ (0) $_{CST}$, defined as follows:

$$s = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{x})^2}$$

$\bar{x}$ is the mean average value of the sample for $C_d \cdot A_{cr}$ (0) $_{CST}$, defined as follows

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$$

n is the number of constant speed tests for the considered vehicle configuration

x_i is the air drag value $C_d \cdot A_{cr}$ (0) $_{CST}$ obtained from a single constant speed test

t is the score for the 95% confidence interval of the double-sided t-distribution, as set out in Table 1

Table 1

# tests	t
3	4,303
4	3,182
5	2,776
6	2,571
7	2,447
8	2,365
9	2,306
10	2,262
11	2,228

(iii) A minimum of three valid constant speed tests shall be performed for each vehicle configuration and taken into account in the calculation.

(iv) If the criterion set out in point (ii) of this subparagraph is not met, additional constant speed tests shall be performed.

(v) If the criterion set out in point (ii) of this subparagraph is not reached after performing eleven valid constant speed tests, all the tests shall be considered void for this vehicle configuration and may not be used for the purpose of this Appendix.

(vi) The reference value for the difference in air drag between the two vehicles $\Delta C_d \cdot A_{cr}$ (0) $_{CST}$ shall be calculated as follows:

$$\Delta C_d \cdot A_{cr} (0)_{CST} = C_d \cdot A_{cr} (0)_{CST,avg,A} - C_d \cdot A_{cr} (0)_{CST,avg,B}$$

(e) The compliance of the CFD method shall be demonstrated by fulfilling the following criterion:

$$\Delta C_D \cdot A_{cr}(0)_{CST} - TOL < \Delta C_D \cdot A_{cr}(0)_{CFD} < \Delta C_D \cdot A_{cr}(0)_{CST} + TOL$$

Where

$$TOL = 0{,}035 \cdot \frac{C_D \cdot A_{cr}(0)_{CST,avg\,A} + C_D \cdot A_{cr}(0)_{CST,avg\,B}}{2}$$

2. The application for approval of the CFD method shall be accompanied by the following information for each vehicle A and B:

   (a) CFD software used including version number information

   (b) Values for $C_D \cdot A_{cr}$ (0) $_{CFD}$ in m^2

   (c) The SHA256 hash of the CFD simulation file, including geometry data, domain discretisation and flow field results. If this information is split into several files by the software used, then these files shall be stored under a single compressed file (e.g. *.zip or equivalent) and the SHA256 hash shall correspond to this single compressed file. The corresponding original simulation data should be kept by the manufacturer for 10 years and must be made available to the type approval authority on request.

   (d) Raw data of the evolution of $C_D \cdot A_{cr}$ (0) $_{CFD}$ versus iteration (for steady-state methods) or versus time (for transient methods)

   (e) Post-processing images of the CFD simulations according to the principles as illustrated by Figures 3 to 6 in Annex V of Implementing Regulation (EU) 2022/1362

   (f) Values for $C_D \cdot A_{cr}$ (0) $_{CST}$ and $C_D \cdot A_{cr}$ (0) $_{CST,avg}$

   (g) Air drag information document as set out in Appendix 2 to this Annex accompanied by test reports for each valid constant speed test

3. The approval of the CFD method shall be carried out separately for application on lorries and on buses.

4. If the compliance of the CFD method is demonstrated in accordance with points 1 and 2, the approval authority shall issue a licence in the form of the document as set out in Appendix 11.

5. The approval of the CFD method shall be renewed in any of the following cases:

   (a) a change is made to the CFD method that could potentially affect the validity of the results

   (b) After 4 years of approval of the CFD method

   (c) At the request of the approval authority

If the approval of the CFD method is not renewed, the approval of the CFD method shall be considered withdrawn, and the CFD method shall no longer be used for the purpose of this Annex.

Within the first 4 years of initial approval, any renewal of the approval of the CFD method may use the original set of data from constant speed testing. After that, a new set of test data performed on different vehicles shall be provided for the renewal of the approval of the CFD method.

Appendix 11

MODEL OF A LICENCE TO APPLY A CFD METHOD FOR AIR DRAG DETERMINATION

Maximum format: A4 (210 × 297 mm)

LICENCE TO APPLY A CFD METHOD FOR AIR DRAG DETERMINATION

Communication concerning: – granting[1] – refusal[1] – withdrawal[1]	Administration stamp

[1]delete if not applicable

of the licence to apply a CFD method with regard to air drag determination in accordance with Annex VIII to Regulation (EU) 2017/2400.

CFD method licence number (following the numbering system set out in point 2 of Appendix 8, with the exception of the additional letter to section 3 ‘P’ replaced by ‘CFD’):

Reason for refusal / withdrawal:

SECTION I

0.1. Name and address of the manufacturer:

0.2. Vehicles covered by licence (lorries, buses):

0.3. CFD software used including version number information

0.4. SHA256 hashes in accordance with point 2. item (c) of this Appendix

SECTION II

1. Approval authority responsible for the assessment

2. Date of the assessment report

3. Number of the assessment report

4. Remarks (if any)

5. Place

6. Date

7. Signature

Attachments (for each vehicle configuration A and B)

1. Raw data of the evolution of $C_D \cdot A_{cr}$ (0) $_{CFD}$

2. Post-processing images of the CFD simulations

3. Air drag information document

Test reports for each valid constant speed test'.

ANNEX VIII

Annex IX is amended as follows:

(1) point 2, point (63) is replaced by the following:

'(63) R-744 heat pump' means a continuous (i.e. electrically driven) heat pump which uses R-744 refrigerant as working medium (HVAC system);';

(2) in point 3.3.2, in table 7, in row 'Alternator', in sub-row 'Alternator Technology', in column 'Explanations' the last sentence is replaced by the following:

'For PEV or FCHV no input is required.';

(3) in point 3.4.1.2, in table 10, the 'Compressor clutch (P311)' column is replaced by the following:

'

none
none
none
none
visco
visco
visco
visco
mechanically
mechanically
mechanically

mechanically
None
none

’;

(4) in point 3.5.2, table 14 is amended as follows:

(a)in the rows ‘Heat pump type for cooling driver compartment’ to ‘Heat pump type for heating passenger compartment’, in the column ‘Explanations’ the following text is added:

‘For PEV and FCHV only continuous (i.e. electrically driven) heat pump types are allowed inputs (i.e. ‘R-744’ or ‘non R-744 continuous’).’;

(b) in the rows ‘Water electric heater’ to ‘Other heating technology’, in the column ‘Explanations’ the text is replaced by the following:

‘Input to be provided only for HEV, FCHV and PEV.’;

(5) point 3.6 is amended as follows:

(a) ‘Table 12’ is renamed to ‘Table 15’;

(b) the paragraph after Table 15 is replaced by the following:

‘In the case of multiple PTOs mounted to the transmission, only the component with the highest losses in accordance with Table 15, for its combination of criteria ‘PTOShaftsGearWheels’ and ‘PTOShaftsOtherElements’, shall be declared. For medium lorries and heavy buses, no declaration of transmission PTOs is foreseen.’.

ANNEX IX

Annex Xa is amended as follows:

(1) in point 1, the first, the second and the third paragraphs are replaced by the following:

‘This Annex sets out the requirements for the verification testing procedure, which is the test procedure for verifying the CO_2 emissions of new heavy-duty vehicles.

The verification testing procedure consists of an on-road test to verify the CO_2 emissions of new vehicles after production. It shall be carried out by the vehicle manufacturer and supervised by the approval authority that granted the licence to operate the simulation tool. In case of heavy buses the verification testing procedure shall be performed by the manufacturer of the primary vehicle.

During the verification testing procedure the torque and speed at the driven wheels, the engine speed, the fuel consumption, the pollutant emissions and the other relevant parameters listed in point 6.1.6 shall be measured. The measured data shall be used as input to the simulation tool, which uses the vehicle-related input data and the input information from the determination of the CO_2 emissions and fuel consumption of the vehicle. For the verification testing procedure simulation, the instantaneously measured wheel torque and the rotational speed of the wheels as well as the engine speed shall be used as input. To pass the verification testing procedure the CO_2 emissions calculated from the measured fuel consumption shall be within the tolerances set out in point 7 compared to the CO_2 emissions from the verification testing procedure simulation. Figure 1 gives a schematic picture of the verification testing procedure method. The evaluation steps as performed by the simulation tool in the verification testing procedure simulation are described in Appendix 1 of this Annex.';

(2) in point 2, point (4) is replaced by the following:

'(4) 'actual mass of the vehicle for VTP' is the actual mass of the vehicle as defined in Article 2(6) of Regulation (EU) 2021/535, but with a full tank and plus the additional measurement equipment as set out in point 5, plus the actual mass of the trailer or semitrailer in accordance with 6.1.4.1;';

(3) point 3 is amended as follows:

(a) points (b) and (c) are replaced by the following:

'(b) The vehicle selection shall be made by the approval authority that granted the licence to operate the simulation tool based on proposals from the vehicle manufacturer. In case of heavy buses, the selection shall be made by the approval authority that granted the licence to operate the simulation tool to the primary vehicle manufacturer.';

(c) Only vehicles with one driven axle shall be selected for the verification test. Hybrid electric, pure electric and fuel cell vehicles shall not be selected for the verification test.';

(b) in table 1, table notes (*) and (**) are replaced by the following:

'(*) The VTP shall be performed within the first two years.

(**) The total of all heavy lorries, medium lorries and primary buses produced by a manufacturer falling within the scope of this regulation is to be considered and medium lorries, heavy lorries and heavy buses need to be covered by the VTP over a six-year time span.';

(c) (c) point (e) is replaced by the following:

'(e) Vehicles which do not use standard values for CO_2 certification of their components, separate technical units or systems instead of measured values for the transmission and for the axle losses shall be preferably tested. In case no vehicles comply with the requirements set out in points (a) to (c), only the verification of the input information and input data and data handling shall be performed in accordance with point 6.1.1.';

(4) in point 4, the first paragraph is replaced by the following:

'Each vehicle for the verification test shall be in the condition resembling its intended placing on the market. No changes in hardware such as lubricants or in the software such as auxiliary controllers are allowed. The tyres may be replaced by measurement tyres of a diameter that shall not exceed ± 10 % of the diameter of the original tyre.';

(5) in point 5.6, the following paragraph is added:

'For heavy buses the status of the compressor of the pneumatic system shall be recorded. Phases where pressurised air is delivered to the reservoir shall be labelled in the measurement data according to the provisions as given in Table 4 of this Annex. The compressor status shall be monitored either via recording of the system pressure or via available CAN signals.';

(6) in point 5.7, second indent, the formula, the entry 'β' is replaced by the following:

‘

β	=	0,001 [K^{-1}] (Temperature correction factor)

’;

(7) in point 5.9, in table 2, the row ‘Wheel torque’ is replaced by the following:

‘

Wheel torque	For 10 kNm calibration (over the entire calibration range): i. Non linearity[3]: < ± 40 Nm for heavy lorries and heavy buses < ± 30 Nm for medium lorries ii. Repeatability[4]: < ± 20 Nm for heavy lorries and heavy buses < ± 15 Nm for medium lorries iii. Crosstalk: < ± 20 Nm for heavy lorries and heavy buses < ± 15 Nm for medium lorries (only applicable for rim torque meters) iv. Measurement rate: ≥ 20 Hz	< 0,1 s

3 Non linearity means the maximum deviation between ideal and actual output signal characteristics in relation to the measured value in a specific measuring range.

4 Repeatability means closeness of the agreement between the results of successive measurements of the same measured value carried out under the same conditions of measurement.

’;

(8) the following points are inserted after point 5.11:

‘5.12. Distance travelled

If the vehicle is equipped with an on-board device for the monitoring and recording of fuel and/or energy consumption and mileage of motor vehicles, in accordance with the requirements referred to in point (b) of Article 5c of Regulation (EC) 595/2009, the mileage shall be recorded from the device.

5.13. Engine fuel rate

If the vehicle is equipped with an on-board device for the monitoring and recording of fuel and/or energy consumption and mileage of motor vehicles, in accordance with the requirements referred to in point (b) of Article 5c of Regulation (EC) 595/2009, the instantaneous value of the engine fuel rate as well as the total fuel consumed at test start and end shall be recorded from the device.

5.14 Vehicle total mass

If the vehicle is equipped with an on-board mass-monitoring device for determining and recording the payloads or total weight of vehicles, in accordance with the requirements referred to in point (b) of Article 5c of Regulation (EC) 595/2009, the instantaneous value of the vehicle total mass shall be recorded from the device.';

(9) in point 6.1.1, the following subparagraph is added:

'In case of heavy buses the primary vehicle manufacturer shall make available the input information and input data as well as the manufacturer's records file and the completed vehicle manufacturer shall make available the vehicle information file and the customer information file.';

(10) point 6.1.1.1 is amended as follows:

(a) in point (c), the first paragraph is replaced by the following:

'Engine torque limitations declared in the input to the simulation tool shall be subject to a verification in the VTP if they are declared for any of the highest 50 % of the gears (e.g. for any of the gears 7 to 12 of a 12-gear transmission) and if one of the following cases applies:';

(b) point (e)(vii) is replaced by the following:

'(vii) air drag;';

(11) point 6.1.1.2 is replaced by the following:

'6.1.1.2 Verification of the vehicle mass

If requested by the approval authority that granted the licence to operate the simulation tool, the determination of masses by the manufacturer shall be verified in accordance with point 2 of Section G of Part 2 of Annex VIII of Regulation (EU) 2021/535. Where that verification fails, the corrected actual mass as defined in point 2(4) of Annex III to this Regulation shall be determined. In the case of heavy buses, the mass of the completed vehicle shall be verified.';

(12) in point 6.1.4.1. the following paragraph is added:

'Heavy buses of the vehicle groups defined in Table 4, 5 and 6 of Annex I shall be tested with the final bodies of the complete or completed vehicle.';

(13) in point 6.1.4.2, the second paragraph is replaced by the following:

'For heavy lorries of groups 1s, 1, 2 and 3, medium lorries and for heavy buses the payload shall be in the range of 55 % to 75 % of the maximum authorised weight in accordance with 96/53/EC for the specific vehicle or vehicle combination.';

(14) point 6.1.4.4 is replaced by the following:

'6.1.4.4 Settings for auxiliaries

All settings influencing the auxiliary energy demand shall be set to minimum reasonable energy consumption where applicable. The air conditioning shall be switched off and venting of the cabin or the driver compartment shall be set lower than medium mass flow. Additional energy consumers not necessary to run the vehicle shall be switched off. External devices to provide energy on board, such as external batteries, are allowed only for running the extra measurement equipment for the verification testing procedure listed in Table 2, but shall not provide energy to vehicle equipment that will be present when placing the vehicle on the market. In case of heavy busses, door opening and kneeling at stops shall not be considered in the verification test.’;

(15) in point 6.1.5.5, the following paragraphs are added:

‘If the vehicle is equipped with fuel-powered auxiliary heaters, only the fuel consumption of the internal combustion engine shall be measured.

Where applicable, the recording of the vehicle total mass and engine fuel rate signals as determined by the OBFCM device shall start latest once the fuel consumption measurement has started and end together with the fuel consumption measurement. The lifetime values of the mileage and total fuel consumption, as determined by the OBFCM device, shall be recorded at the start of the fuel consumption measurement and at the end of the OBFCM fuel consumption measurement.’;

(16) point 6.1.5.7 is amended as follows:

(a) the first paragraph is replaced by the following:

‘The boundary conditions to be met for a valid verification test are set in Tables 3 to 3d.’;

(b) the third paragraph is deleted;

(c) the following tables are added:

‘

Table 3c			
Parameters for a valid verification test for high floor heavy buses			
No.	Parameter	Min.	Max.
4	Distance based share urban driving	12 %	40 %
5	Distance based share rural driving	10 %	30 %
6	Distance based share motorway driving	30 %	-
7	Time share of idling at stand still	-	10 %

Table 3d			
Parameters for a valid verification test for low floor heavy buses			
No.	Parameter	Min.	Max.
4	Distance based share urban driving	75 %	90 %
5	Distance based share rural driving	10 %	25 %
6	Distance based share motorway driving	-	0 %

7	Time share of idling at stand still	-	10 %

’;

(17) point 6.1.6, table 4 is amended as follows:

(a) the following row is inserted after the row ‘fuel flow’:

‘

Compressor pneumatic system status	[-]	<PS_comp_active>	1 = active (compressor delivering to pneumatic system), 0 = not active this input data is only relevant for heavy buses

’;

(b) in row ‘CO_2 mass flow’, in column ‘Heading input data’ the following text is inserted:

‘<CO_2>’;

(c) (c) the following rows are added:

‘

OBFCM mileage	[km]	<ml_obfcm>	Mileage in accordance with point 5.12 (if applicable)
OBFCM engine mass fuel rate	[g/s]	<fcm_obfcm>	Engine mass fuel rate in accordance with point 5.13 (if applicable)
OBFCM engine volume fuel rate	[l/s]	<fcv_obfcm>	Engine volume fuel rate in accordance with point 5.13 (if applicable)
OBFCM vehicle total mass	[kg]	<m_obfcm>	Vehicle total mass in accordance with point 5.14 (if applicable)

’:

(18) the following point is inserted after point 6.1.6:

‘6.2. Additional verifications

For heavy buses, the correspondence of the tested vehicle with the following parameters shall be verified:

i. Technical Permissible Maximum Laden Mass

ii. Vehicle code

iii. Class of vehicle

iv. Low entry (if applicable)

v. Number of passenger seats

vi. Height of the integrated body';

(19) point 7.1 is replaced by the following:

'7.1 Input to the simulation tool

The following inputs to the simulation tool shall be made available: Input data and input information;

(a) In case of medium and heavy lorries

(i) Manufacturer's records file;

(ii) Customer information file;

(iii) Processed measurement data in accordance with Table 4;

(iv) Further information in accordance with Table 4a.

(b) In case of heavy buses

(v) Input data and input information as defined for the primary heavy bus;

(vi) Manufacturers records file for the primary heavy bus;

(vii) Vehicle information file for the primary vehicle;

(viii) Customer information file for the completed vehicle;

(ix) Vehicle information file for the completed vehicle;

(x) Processed measurement data according to Table 4;

(xi) Further information according to Table 4a.';

(20) in point 7.2.1, the following paragraph is inserted after the first paragraph:

'For heavy buses the vehicle information file and the customer information file of the completed vehicle shall also be verified.';

(21) point 7.3 is replaced by the following:

'7.3. Pass/Fail check

The vehicle shall pass the verification test if the C_{VTP} ratio determined in accordance with 7.2.2. is equal or smaller than the tolerance set out in Table 5.

For a comparison with the declared CO_2 emissions of the vehicle in accordance with Article 9, the verified CO_2 emissions of the vehicle shall be determined as follows:

$CO_{2verified} = C_{VTP} \times CO_{2declared}$

where:

$CO_{2verified}$	=	verified CO_2 emissions of the vehicle in [g/t-km] for medium and heavy lorries and in [g/pkm] for heavy buses
$CO_{2declared}$	=	declared CO_2 emissions of the vehicle in [g/t-km] for medium and heavy lorries and in [g/pkm] for heavy buses

If a first vehicle does not meet the pass criterion for the verification testing procedure as set out in Table 5, up to two additional tests shall be performed on the same vehicle or two more similar vehicles may be tested on request of the vehicle manufacturer. For the evaluation of the pass criterion set out in Table 5, the arithmetic average of the C_{VTP} ratios obtained from all the tests performed shall be used. If the pass criterion is not reached, the vehicle fails the verification testing procedure.

Table 5	
Pass criterion for the verification test	
Pass criterion for the verification testing procedure	C_{VTP} ratio ≤ 1,075

Where C_{VTP} is lower than 0,925, the results need to be reported to the Commission for further analysis to determine the cause.';

(22) point 8.1.1 is replaced by the following:

'8.1.1. Name and address of the vehicle manufacturer[14]

14 For heavy buses only primary vehicle manufacturer';

(23) point 8.2.3 is replaced by the following:

'8.2.3. Vehicle category (N_2, N_3, M_3)';

(24) the following point is added after point 8.13.14.7.:

'8.13.14.8. CO_2 (g/kWh)';

(25) the following points are inserted after point 8.13.14.7:

'8.13.15 OBFCM values in the verification test (if applicable)

8.13.15.1 OBFCM mileage reading at test start of the fuel consumption measurement from the signal referred to in point 5.12 (km)

8.13.15.2 OBFCM mileage reading at test end of the fuel consumption measurement from the signal referred to in point 5.12 (km)

8.13.15.3 OBFCM total mass fuel consumed from the lifetime signal referred to in point 5.13 at the beginning of the fuel consumption measurement (kg)

8.13.15.4 OBFCM total mass fuel consumed from the lifetime signal referred to in point 5.13 at the end of the fuel consumption measurement (kg)

8.13.15.5 OBFCM total volume fuel consumed from the lifetime signal referred to in point 5.13 at the beginning of the fuel consumption measurement (l)

8.13.15.6 OBFCM total volume fuel consumed from the lifetime signal referred to in point 5.13 at the end of the fuel consumption measurement (l)

8.13.15.7 OBFCM accumulated engine mass fuel rate values from the instantaneous signal referred to in point 5.13 (kg)

8.13.15.8 OBFCM accumulated engine volume fuel rate values from the instantaneous signal referred to in point 5.13 (l)

8.13.15.9 OBFCM average total mass from the signal referred to in point 5.14 (kg)

8.13.15.10 odometer reading at test end of the fuel consumption measurement (km)

8.13.15.11 total mass fuel consumption value in the verification test measured (kg)

8.13.15.12 total volume fuel consumption value in the verification test measured (l)';

(26) in Appendix 1, in Part A, point 3 is replaced by the following:

'3. Determination of the brake specific fuel consumption simulated by the simulation tool ($BSFC_{sim}$)

In the verification test mode of the simulation tool the measured wheel power is applied as input to the backward simulation algorithm. The gears engaged during the verification test are determined by calculating the engine speeds per gear at the measured vehicle speed and selecting the gear that provides the engine speed closest to the measured engine speed. For APT transmissions during phases with active torque converter, the actual gear signal from the measurement is used.

The loss models for axle gear, angle drive, retarders, transmissions and PTOs are applied in a similar way as in the declaration mode of the simulation tool.

For power demand of auxiliary units concerning steering pump, pneumatic system, electric system and HVAC system the generic values as implemented per technology in the simulation tool are applied. For heavy buses the recorded signal of the pneumatic system compressor status is also taken into account. For calculation of the power demand of the engine cooling fan the following formulas are applied:

Case a) non-electrically driven engine cooling fans:

$$P_{fan(t)} = C1 \cdot \left(\left(\frac{n_{fan(t)}}{C2}\right)^3 \cdot \left(\frac{D_{fan}}{C3}\right)^5\right) \cdot C4$$

where:

P_{fan} = power demand engine cooling fan [kW]

t = time node [s]

n_{fan} = measured rotational speed of the fan [rpm]

D_{fan} = diameter of the fan [mm]

C1 = 7,32 kW

C2 = 1200 rpm

C3 = 810 mm

C4 = for heavy buses, the factor set out in Table 6, for other vehicle categories it is equal to 1

Table 6

C4 factors for calculation of engine cooling fan power demand for heavy buses

Fan drive cluster	**Fan control**	**C4**
Crankshaft mounted	Electronically controlled visco clutch	1,05
	Bimetalic controlled visco clutch	1,05
	Discrete step clutch coupling, 2 stages (0% / stage 1 / stage 2)	1,05
	Discrete step clutch coupling, 3 stages (0% /stage 1/ stage 2 / stage 3)	1,05
	On/off clutch	1,05

	Electronically controlled visco clutch	1,11
	Bimetalic controlled visco clutch	1,11
	Discrete step clutch coupling, 2 stages (0% / stage 1 / stage 2)	1,11
	Discrete step clutch coupling, 3 stages (0% /stage 1/ stage 2 / stage 3)	1,11
Belt driven or via transmission	On/off clutch	1,11
	Variable displacement pump	1,75
Hydraulically driven	Constant displacement pump	2,25

Case (b) electrically driven engine cooling fans:

$P_{fan(t)} = P_{el(t)} \cdot 1{,}43$

P_{fan} = power demand engine cooling fan [kW]

t = time node [s]

P_{el} = electrical power at the terminals of the engine cooling fan(s) as measured in accordance with point 5.6.1.

In the case of vehicles with engine stop-start events during the verification test, similar corrections for auxiliary power demand and energy to re-start the engine as applied in the declaration mode of the simulation tool are applied.

The simulation of the engines instantaneous fuel consumption $FC_{sim(t)}$ is performed for each 0,5 second time interval as follows:

- Interpolation from the engine fuel map using measured engine speed and resulting engine torque from the backward calculation including engines rotational inertia calculated from measured engine speed;

- The engine torque demand as determined above is limited to the certified engine full-load capabilities. For those time intervals the wheel power in the backward simulation is reduced accordingly. In the calculation of $BSFC_{sim}$ as set out below this simulated wheel power trace ($P_{wheel,sim(t)}$) is taken into consideration.

- A WHTC correction factor is applied corresponding to the allocation of urban, rural and motorway based on the definitions as given in point 2(8) to 2(10) and the measured vehicle speed.

The brake specific fuel consumption calculated by the simulation tool $BSFC_{m-c}$ as applied in 7.2.2 for calculation of the C_{VTP} factor is calculated as follows:

$$BSFC_{sim} = \frac{\left(\sum_{tstart}^{tend} FC_{sim(t)} \cdot \Delta t\right) + FC_{ESS,corr}}{W_{wheel,pos,sim}}$$

where:

$BSFC_{sim}$ = brake specific fuel consumption determined by the simulation tool for the verification test [g/kWh]

t	=	time node [s]
FC_{sim}	=	engines instantaneous fuel consumption [g/s]
Δt	=	time increment duration = 0,5 [s]
$FC_{ESS,corr}$	=	correction of fuel consumption regarding auxiliary power demand resulting from engine stop start (ESS) as applied in the declaration mode of the simulation tool [g]
$W_{wheel,pos,sim}$	=	positive wheel work determined by the simulation tool for the verification test [kWh]

$$W_{wheel,pos,sim} = \sum_{t_{start}}^{t_{end}} \frac{\max\left(P_{wheel,sim(t)}, 0\right)}{3600 \cdot fs}$$

fs	=	Simulation rate = 2 [Hz]
$P_{wheel,sim}$	=	Simulated wheel power for the verification test [kW]

In the case of dual-fuel engines, $BSFC_{sim}$ is determined for both fuels separately.

ANNEX X

Annex Xb is amended as follows:

(1) in point 2, the following points are added:

‘(54) ‘FCS UUT’ means the fuel cell system (‘FCS’) or representative fuel cell (‘FC’) subsystem to be actually tested.

(55) ‘balance of plant’ or ‘BoP’ means the assembly of all the supporting components and auxiliary systems of an FCS needed to deliver the energy, other than the generating unit itself. These may include transformers, inverters, supporting structures etc., depending on the type of plant.

(56) ‘BoP-component’ or ‘BoPC’ means a component that belongs to a BoP.

(57) ‘air processing sub-system’ or ‘APS’ means an assembly of components that delivers air (oxygen containing media) for reaction in the FCS. The APS can provide air as required to a) the fuel processing sub-system, b) thermal management sub-system (TMS) and c) fuel cell stack-sub-system (FCSS). The APS may include filtration, purification, compression, humidification as well as flow control components.

(58) ‘fuel processing sub-system’ or ‘FPS’ means the assembly of components that chemically or physically converts the supplied fuel to a form suitable for use in the fuel cell stack sub-system. The fuel processing sub-system may include pressure

regulation, humidification, and mixing components. The fuel processing sub-system also may be referred to as the fuel processor subsystem or the fuel processor.

(59) ‘thermal management sub-system’ or ‘TMS’ means the assembly of components that provides both thermal and water management for the FCS. The thermal management sub-system may include an accumulator, pump, radiator, and/or condenser. It may also provide water recovery and process humidification functions.

(60) ‘fuel cell stack sub-system’ or ‘FCSS’ means the assembly containing one or more fuel cell stacks in which by means of an electrochemical reaction between fuel and oxidant chemical energy is transferred into electric energy. The FCSS generally includes connections for conducting fuel, oxidant, and exhaust; electrical connections for the power delivered by the stack sub-system; and means for monitoring electrical loads, which are for interface to the FCS. Additionally, the FCSS may incorporate means for conducting additional fluids (e.g., cooling media, inert gas), means for detecting normal and/or abnormal operating conditions, enclosures or pressure vessels, and ventilation systems. The FCSS is also known as a fuel cell module, fuel cell power module, or fuel cell stack assembly.

(61) ‘fuel cell control sub-system’ means a system that controls and/or monitors FCS conditions and automatically responds to vehicle power demands while preventing hazardous conditions and damage to the FCS. The automatic control system generally includes a microprocessor-based device with input and output functions and may provide a diagnostic or troubleshooting function.

(62) ‘power distribution sub-system’ (PDS) means the collection of components that connects the FCSS to the power conditioning system and that converts power for FCS use. The power distribution sub-system may include cables, switches and/or contactors and/or relays, buses, other connectors, and instrumentation. The PDS has only DC power as input.

(63) ‘fuel cell system’ or ‘FCS’ means an energy converter which transforms chemical energy into electric energy via in series connected electrochemical cells, referred to as a fuel cell stack. The FCS includes all necessary balance of plant components to provide fuel, oxygen (e.g. in form of air), cooling and media conditioning to ensure a sound operation of the FC-stacks. Different configurations of FCS are known, also referred to as different types or variants, the relevant types are described in Table 9.

(64) ‘power conditioning system’ or ‘PCS’ means the collection of components that converts the electric energy generated by the fuel cell stack(s) into electricity useful for vehicle purposes. The PCS includes at least a voltage regulator (DC/DC) and/or voltage converters (DC/AC). It might be connected to the cooling media loop. It provides the interface between the FCS and the battery and other electrical vehicle loads.

(65) ‘water treatment sub-system’ or ‘WTS’ means the assembly of components that provides the treatment necessary for the process water used in the fuel cell system (FCS). For example, the WTS may include a demineralizing / deionizing resin bed and instrumentation and may provide water recovery and process humidification functions.

(66) ‘inner cooling loop’ or ‘ICL’ means in FCS with a split of inner (primary) and outer (secondary) cooling loops of BoPC, a closed coolant loop that is connected to the cooling media of the different BoPC and is integrated into the FCS as part of the TMS. Multiple inner cooling loops may exist inside an FCS, e.g. one for the power electronics (PDS, PCS) and one for the FCSS.

(67) ‘outer cooling sub-system’ means the collection of components to exchange waste heat of the FCS, which is stored inside the cooling fluid, with the environment. It may include radiators, pumps, fans and other actuators.

(68) ‘external electric components’ means all electric components that are not part of the FCS and / or are electrically not connected to the DC power between FCSS and PCS. These include the electric machines of the powertrain and the REESS.

(69) ‘relative transition slope’ or ‘RTS’ means a coefficient that express the change rate of the set-point for the electric power output of the FCS. RTS puts into relation the change in time against the upper electric power output of the FCS.

(70) ‘system conditioning operating point’ or ‘SCOP’ means a set point for the electrical power output of the system that is suited to condition the FCS in the specified duration of the conditioning phase.

(71) ‘setpoint’ or ‘SP’ means the desired or target value for an essential variable, or process value of a system.

(72) ‘process value’ or ‘process variable’ or ‘PV’ is the current measured value for an essential variable, or process value of a system.’;

(2) in point 3.1, in table 1, the following rows are inserted after the row ‘Torque’:

‘

Fuel mass flow*	1,0 % of the analyzer reading or 0,5 % of max. calibration [2)] whichever is larger
Air/oxidant mass flow[1]	1,0 % of the analyzer reading or 0,5 % of max. calibration [2)] whichever is larger
Cooling liquid mass flow	2,5 % of the analyzer reading or 0,1 % of max. calibration [2)] whichever is larger
Cooling liquid volume flow	2,5 % of the analyzer reading or 0,1 % of max. calibration [2)] whichever is larger
Cooling liquid pressure	0,5 % of the analyzer reading or 0,1 % of max. calibration [2)] whichever is larger
Fuel, ambient, air pressure	1 kPa

* If volume flow is metered, the accuracy shall be transferred as accuracy of mass flow measurement.’;

(3) in point 3.1, in table 1, the following row is inserted after the row ‘Temperature’:

‘

Dew point temperature	±2,5 K of the analyzer reading or 1,0 % of max. calibration [2)] whichever is larger

‘;

(4) the following points are inserted after point 3.2:

‘3.2.1 Data recording for the purpose of FCS-certification

For the purpose of FCS-certification the sampling frequency shall be constant with a sample frequency of at least 10 Hz for all values.

3.2.2 Sign convention of energy and media exchange over UUT-boundary

The flow of media or energy that is leaving the UUT shall have a negative sign and vice-versa.';

(5) in point 4.1.3, the following paragraph is added:

'The voltage for unlimited operating capability shall be a representative voltage range typically applied in real vehicles and shall not necessarily reflect the technically minimum/maximum allowed input voltage to the UUT, and shall not reflect extreme boundary conditions where the operating capabilities of the UUT are limited by high-level vehicle control that is not part of the actual UUT control logics (e.g. reduction of available propulsion torque of UUT due to limitations in the vehicle's REESS).';

(6) the following point is inserted after point 4.1.8.4:

'4.1.8.5 Installation requirements

The installation of the UUT on the test bed shall be done with an angle of inclination as for installation in the vehicle according to the homologation drawing ±1°. Alternatively, it shall be installed at 0°±1° on the test bed for covering all different installation variants in the vehicle.';

(7) point 4.2.2 is amended as follows:

(a) the second paragraph is replaced by the following:

'For IEPC with multispeed gearbox the test shall be performed in accordance with the following provisions:

(a) the test shall be performed for the gear with the gear ratio closest to 1;

(b) in case the gear ratios of two gears have the same distance to a gear ratio of 1, the test shall be performed for the gear with the higher of those two gears ratios;

(c) additionally, the test may be performed also for all other forward gears of the IEPC so that a dedicated dataset for each forward gear of the IEPC is determined.';

(b) the following paragraph is added:

'The test of maximum and minimum torque limits shall be performed for each applicable variant (i.e. either voltage level or forward gear in case of an IEPC with multispeed gearbox) declared in accordance with point 4.2.2.1 by applying the provisions laid down in points 4.2.2.2, 4.2.2.3 and 4.2.2.4 separately to each of those applicable variants.';

(8) in point 4.2.2.1, the second sentence is replaced by the following:

'That declaration shall be separately made for each forward gear of an IEPC with multispeed gearbox measured in accordance with point 4.2.2 and also for each of the two voltage levels $V_{min,Test}$ and $V_{max,Test}$.';

(9) point 4.2.6.2 is replaced by the following:

'4.2.6.2 Operating points to be measured

For IEPC with multispeed gearbox the setpoints for rotational speed and torque required to be measured during the actual test run shall be determined for each single forward gear in accordance with points 4.2.6.2.1, 4.2.6.2.2 and 4.2.6.2.3.';

(10) point 4.2.6.2.1 is amended as follows:

(a) in the second paragraph, the introductory wording is replaced by the following:

‘In the case of an IEPC with multispeed gearbox where the torque limits were only determined for a single gear in accordance with points 4.2.2(a) and 4.2.2(b), a separate dataset of setpoints for rotational speed of the UUT shall be defined for each single forward gear based on the following provisions:’;

(b) the following paragraph is added:

‘In the case of an IEPC with multispeed gearbox where the torque limits were determined for each forward gear in accordance with point 4.2.2(c), a separate dataset of setpoints for rotational speed of the UUT shall be defined for each single forward gear based on the following provisions:

(f) As setpoints for rotational speed of the UUT the same setpoints used for the measurement performed in accordance with point 4.2.2.2 for the respective voltage level and the respective forward gear shall be used.

(g) The speed setpoint for the maximum 30 minutes continuous torque verification performed in accordance with point 4.2.4.2 for the respective voltage level shall be used in addition to the setpoints defined in subpoint (f) of this point. That rotational speed setpoint shall be converted to the respective setpoint for a specific forward gear by the equation defined in subpoint (e) of this point.

(h) Further speed setpoints may be defined in addition to the setpoints defined in subpoints (f) and (g).’;

(11) point 4.2.6.2.2 is amended as follows:

(a) in the second paragraph, the introductory wording is replaced by the following:

‘In the case of an IEPC with multispeed gearbox where the torque limits were only determined for a single gear in accordance with subpoint (a) of point 4.2.2, a separate dataset of setpoints for torque of the UUT shall be defined for each single forward gear based on the following provisions:’;

(b) the following paragraph is added:

‘In the case of an IEPC with multispeed gearbox where the torque limits were determined for each forward gear in accordance with point 4.2.2(c), a separate dataset of setpoints for torque of the UUT shall be defined for each single forward gear based on the following provisions:

(i) At least 10 setpoints for torque of the UUT shall be defined for the measurement for each single forward gear, located both on the positive (i.e. driving) and negative (i.e. braking) torque side by applying the provisions defined in subpoints (a) to (e) of this point for the specific gear.

(j) All resulting torque setpoints that have an absolute value higher than 10 kNm shall not be required to be measured during the actual test run for the specific gear performed in accordance with point 4.2.6.4.’;

(12) the following point is inserted after point 4.2.6.2.2:

‘4.2.6.2.3 Requirements for minimum amount of torque setpoints

For each setpoint for rotational speed defined in accordance with point 4.2.6.2.1 the following requirements shall apply:

(a) There shall be a minimum number of 3 torque setpoints defined in accordance with point 4.2.6.2.2 located on the positive (i.e. driving) side with an absolute torque value lower than or equal to 10 kNm. Those setpoints shall be measured during the actual test run performed in accordance with point 4.2.6.4 and the exceptions laid down in point 4.2.6.2.2(h) and 4.2.6.2.2(j) shall not apply.

(b) There shall be a minimum number of 3 torque setpoints defined in accordance with point 4.2.6.2.2 located on the negative (i.e. braking) side with an absolute torque value lower than or equal to 10 kNm. Those setpoints shall be measured during the actual test run performed in accordance with point 4.2.6.4 and the exceptions laid down in point 4.2.6.2.2(h) and 4.2.6.2.2(j) shall not apply.

(c) In case the number of original torque setpoints defined in accordance with subpoint (a) is 1, the following provisions shall apply:

(i) If an original torque setpoint located higher than 6.66 kNm exists, two new additional torque setpoints shall be defined located equidistant between the original torque setpoint and 0 kNm.

(ii) If no original torque setpoint located higher than 6.66 kNm exists, a new additional torque setpoint at 9.8 kNm shall be defined.

(iii) If no original torque setpoint located higher than 6.66 kNm exists and also no original torque setpoint located lower than 3.33 kNm exists, a new additional torque setpoint shall be defined located equidistant between the lowest positive (i.e. driving) original torque setpoint and 0 kNm.

(iv) If no original torque setpoint located higher than 6.66 kNm exists and also no original torque setpoint located higher than or equal to 3.33 kNm exists, a new additional torque setpoint shall be defined located equidistant between the lowest positive (i.e. driving) original torque setpoint and 9.8 kNm.

(d) In case the number of original torque setpoints defined in accordance with subpoint (a) is 2, the following provisions shall apply:

(i) If no original torque setpoint located higher than 6.66 kNm exists, a new additional torque setpoint at 9.8 kNm shall be defined.

(ii) If an original torque setpoint located higher than 6.66 kNm exists and also an original torque setpoint located lower than 3.33 kNm exists, a new additional torque setpoint shall be defined located equidistant between the lowest and highest positive (i.e. driving) original torque setpoints.

(iii) If an original torque setpoint located higher than 6.66 kNm exists and also an original torque setpoint located higher than or equal to 3.33 kNm exists, a new additional torque setpoint shall be defined located equidistant between the lowest positive (i.e. driving) original torque setpoint and 0 kNm.

(e) In case the number of original torque setpoints defined in accordance with subpoint (b) is 1, the following provisions shall apply:

(i) If an original torque setpoint located lower than -6.66 kNm exists, two new additional torque setpoints shall be defined located equidistant between the original torque setpoint and 0 kNm.

(ii) If no original torque setpoint located lower than -6.66 kNm exists, a new additional torque setpoint at -9.8 kNm shall be defined.

(iii) If no original torque setpoint located lower than -6.66 kNm exists and also no original torque setpoint located higher than -3.33 kNm exists, a new additional torque setpoint shall be defined located equidistant between the highest negative (i.e. braking) original torque setpoint and 0 kNm.

(iv) If no original torque setpoint located lower than -6.66 kNm exists and also no original torque setpoint located lower than or equal to -3.33 kNm exists, a new additional torque setpoint shall be defined located equidistant between the highest and lowest negative (i.e. braking) original torque setpoints.

(f) In case the number of original torque setpoints defined in accordance with subpoint (b) is 2, the following provisions shall apply:

(i) If no original torque setpoint located lower than -6.66 kNm exists, a new additional torque setpoint at -9.8 kNm shall be defined.

(ii) If an original torque setpoint located lower than -6.66 kNm exists and also an original torque setpoint located higher than -3.33 kNm exists, a new additional torque setpoint shall be defined located equidistant between the highest and lowest negative (i.e. braking) original torque setpoints.

(iii) If an original torque setpoint located lower than -6.66 kNm exists and also an original torque setpoint located lower than or equal to -3.33 kNm exists, a new additional torque setpoint shall be defined located equidistant between the highest negative (i.e. braking) original torque setpoint and 0 kNm.';

(13) in point 4.2.6.4, the sixth paragraph is replaced by the following:

'All operating points shall be held for an operating time of at least 5 seconds. During that operating time the rotational speed of the UUT shall be held at the rotational speed setpoint within a tolerance of ±1 % or 20 rpm whatever is larger. Additionally, during that operating time, except for the highest and lowest torque setpoint at each rotational speed setpoint, the average torque shall be held at the torque setpoint within a tolerance of ±1 % of the value of the torque setpoint or ±5 Nm (±2 % of the value of the torque setpoint or ±20 Nm in case of the UUT being an IEPC with either a gearbox and/or a differential included) whatever is larger.';

(14) in point 4.3.2, the following paragraph is added:

'In the case of an IEPC with multispeed gearbox where the torque limits were determined for each forward gear in accordance with point 4.2.2(c), the manipulation step shall be done separately for each forward gear.';

(15) point 4.3.3 is amended as follows:

(a) the introductory wording is replaced by the following:

'The data for the drag curve determined in accordance with point 4.2.3 shall be modified in accordance with the following provisions considering that drag torque shall have a negative sign in accordance with the sign conventions laid down in point 4.1.9:';

(b) in subpoint (4), the following sentence is added:

'These values of virtual drag torque shall have a negative sign in accordance with the sign conventions defined in point 4.1.9.';

(16) point 4.3.4 is amended as follows:

(a) the introductory wording is replaced by the following:

‘The data for the EPMC determined in accordance with point 4.2.6.4 shall be extended in accordance with the following provisions for each forward gear measured and also for each of the two voltage levels Vmin,Test and Vmax,Test separately:’;

(b) subpoint (3) is replaced by the following:

‘(3) If at a specific rotational speed setpoint, including the newly introduced data in accordance with points 1 and 2 of this point, a torque setpoint determined in accordance with point 4.2.6.2.2 (a) to (g) and (i) was omitted for the actual measurement in accordance with point 4.2.6.2.2 (h) or point 4.2.6.2.2(j), a new data point representing the omitted point shall be calculated based on the following provisions:

(a) Rotational speed: using the value of the omitted setpoint for the rotational speed.

(b) Torque: using the value of the omitted setpoint for torque.

(c) Inverter power: calculating a new value by means of linear extrapolation according to the subsequent provisions in this subpoint. The parameters of the least squares linear regression line (i.e. slope and y-intercept) for a specific omitted point shall be determined based on the three actually measured points (i.e. data pairs of torque and inverter power) located closest to the torque value from subpoint (b) for the corresponding rotational speed setpoint. The extrapolated value for the inverter power shall be determined by taking the inverter power of the actually measured point located closest to the torque value from subpoint (b) as a starting point and applying only the slope of the specific least squares linear regression line.

(d) For positive torque values, extrapolated values of inverter power resulting in values lower than the measured one at the actually measured torque point located closest to the torque value from subpoint (b) shall be set to the inverter power actually measured at the torque point located closest to the torque value from subpoint (b).

(e) For negative torque values, extrapolated values of inverter power resulting in values higher than the measured one at the actually measured torque point located closest to the torque value from subpoint (b) shall be set to the inverter power actually measured at the torque point located closest to the torque value from subpoint (b).

(f) Notwithstanding the provisions in subpoints (d) and (e), extrapolated values of inverter power resulting in an efficiency of the total IEPC (i.e. determined based on electrical inverter power and mechanical power at component output shaft) higher than one of the following two limits, shall be replaced by a new value of inverter power that reflects exactly the efficiency defined by the limit chosen by the manufacturer: (i) either the resulting efficiency for this specific operating point when the provisions for determining standard values in accordance with Appendix 9 are applied (ii) or the efficiency of the actually measured torque point located closest to the torque value from subpoint (b) decreased by 2 percentage points (e.g. 90,5 %-2%=88,5 %).’;

(17) the following points are added after point 6.4.1:

‘7. Testing of FCS

7.1 Component test procedure for FCS

7.1.1 Fuel quality

The reference fuel as laid down in table 8 shall be used for the test run performed in accordance with point 7.3.

Table 8

Definition of hydrogen reference fuel

Characteristics	*Units*	*Limits*		*Test Method*
		Minimum	*Maximum*	
Hydrogen fuel index	% mole fraction	99,97		(1)
Total non-hydrogen gases	µmol/mol		300	
Lists of non-hydrogen gases and the specification of each contaminant **(6)**				
Water (H_2O)	µmol/mol		5	(5)
Total hydrocarbons(2) except methane (C1 equivalent)	µmol/mol		2	(5)
Methane (CH_4)	µmol/mol		100	(5)
Oxygen (O_2)	µmol/mol		5	(5)
Helium (He)	µmol/mol		300	(5)
Total Nitrogen (N_2) and Argon (Ar) (2)	µmol/mol		300	(5)
Carbon dioxide (CO_2)	µmol/mol		2	(5)
Carbon monoxide (CO) (3)	µmol/mol		0.2	(5)
Total sulfur compounds (4) (H_2S basis)	µmol/mol		0,004	(5)
Formaldehyde (HCHO)	µmol/mol		0,2	(5)
Formic acid (HCOOH)	µmol/mol		0,2	(5)
Ammonia (NH_3)	µmol/mol		0,1	(5)
Total halogenated compounds (5) (Halogenate ion basis)	µmol/mol		0,05	(5)

(1) The hydrogen fuel index is determined by subtracting the “total non-hydrogen gases” in this table, expressed in mole per cent, from 100 mole per cent.

(2) Total hydrocarbons except methane include oxygenated organic species.

(3) The sum of measured CO, HCHO and HCOOH shall not exceed 0,2 µmol/mol

(4) As a minimum, total sulfur compounds include H2S, COS, CS2 and mercaptans, which are typically found in natural gas.

(5) Test method shall be documented. Test methods defined in ISO21087 are preferable.

(6) The analysis of specific contaminants depending on the production process shall be exempted. A vehicle manufacturer shall provide the responsible authority reasons for exempting specific contaminants.

7.2 System boundary of the unit under test and descriptions of specific components

7.2.1 System boundary of the unit under test

The FCS unit under test ('UUT') may comprise different BoPCs, the allowed configurations are set out in table 9. The terminology of the different components is based on the SAE norm J2615. All configurations of FCS have two things in common:

a) they are tested and certified without outer cooling sub-system as a standalone power supply unit without external electric components of the vehicle connected;

b) all of them comprise the APS.

Passive components that may affect the fuel consumption of the FCS shall either be part of the FCS UUT or be fitted inside the test setup to ensure a comparable vehicle-like operation situation.

The FCS UUT shall be set up on the test bed in accordance with the requirements set out in table 9 and points 7.2.2 and 7.2.3. The type of FCS shall be determined dependent on the actual configuration of the FCS UUT on the test bed and one of the type identifiers 'A', 'B', 'C' or 'D' shall be assigned in accordance with the requirements set out in table 9.

7.2.2 Fuel Cell Systems without Power Conditioning Sub-system

If PCS is not included, the correction methods laid down in point 7.5 shall be applied to account for the impact of the power loss due to the PCS efficiency.

7.2.3 Fuel Cell Systems excluding power consuming balance of plant components

The correction methods laid down in point 7.5 shall be applied to account for the power consuming components that are mandatory for the operation of the FCS and are not included in the UUT. All excluded power consuming components shall be listed and their power uptake documented in the information document set out in Appendix 7.

Table 9

Definition of different FCS-variants (Types A to D) for certification

<table>
<tr><th rowspan="2">Sub-System</th><th rowspan="2">Component</th><th colspan="4">Part of FCS</th><th colspan="4">Fitted for certification test</th></tr>
<tr><th>Type_A</th><th>Type_B</th><th>Type_C</th><th>Type_D</th><th>Type_A</th><th>Type_B</th><th>Type_C</th><th>Type_D</th></tr>
<tr><td rowspan="8">APS
(Air Processing Sub-system)</td><td>Inlet particle filter</td><td colspan="4">No</td><td colspan="4">Yes, or test cell equipment(2)</td></tr>
<tr><td>Inlet manifold</td><td colspan="4">No</td><td colspan="4">Yes, or test cell equipment(2)</td></tr>
<tr><td>Intake air charging equipment (e.g. el. turbocharger or compressor)</td><td colspan="4">Yes</td><td colspan="4">Yes</td></tr>
<tr><td>Air flow meter(3)</td><td colspan="4">Yes</td><td colspan="4">Yes</td></tr>
<tr><td>Air inlet duct work</td><td colspan="4">No</td><td colspan="4">Yes, or test cell equipment(2)</td></tr>
<tr><td>Inlet silencer(3)</td><td colspan="4">No</td><td colspan="4">Yes, or test cell equipment(2)</td></tr>
<tr><td>Charge air cooler(3)</td><td colspan="4">Yes</td><td colspan="4">Yes</td></tr>
<tr><td>Humidification(3)</td><td colspan="4">Yes</td><td colspan="4">Yes</td></tr>
<tr><td rowspan="4">TMS</td><td>All coolant pump(s)</td><td colspan="2">Yes</td><td colspan="2">No, or partly</td><td colspan="2">Yes</td><td colspan="2">Yes, else test cell equipment(1)(2)(5)</td></tr>
<tr><td>Radiator</td><td colspan="4">No</td><td colspan="4">Test cell equipment(2)</td></tr>
<tr><td>Ion-Exchanger(3)(6)</td><td colspan="4">Yes</td><td colspan="4">Yes, or test cell equipment(2)(3)</td></tr>
<tr><td>Fan</td><td colspan="4">No</td><td colspan="4">No</td></tr>
</table>

WTS	Water seperator(3)	Yes				Yes			
	Drain Valve(3)(6)	Yes				Yes			
	Exhaust manifold	No				Yes, or test cell equipmentb(2)			
	Connecting pipes	No				Yes, or test cell equipment(2)			
	Silencer(3)	No				Yes, or test cell equipment(2)			
	Tail pipe	No				Yes, or test cell equipment(2)			
	Exhaust H2-Sensor	No				Yes, or test cell equipment(2)			
FPS	Fuel Supply System (FSS)	No				Yes, or test cell equipment(2)			
	Pressure regulator / Injector	Yes				Yes			
	Fuel heat exchanger(3)	Yes				Yes			
	Active Recirculation device (Compressor/Pump)(3)	Yes				Yes			
	Passive Recirculation Devise (Injector/Ejector)(3)	Yes				Yes			
	Filters[3]	Yes				Yes			
FCSS	*	Yes				Yes			
PDS	Electrical components (e.g. cables, switches, relays)*	Yes				Yes(4)			
PCS	Voltage regulator (DC/DC) and/or converter (DC/AC)	Yes	No	Yes	No	Yes	Test cell equip-ment(1)(2)	Yes	Test cell equip-ment(1)(2)
fuel cell control sub-system	Processing/control unit	Yes				Yes			
	Software of specified version	Yes				Yes(4)			

* no further break-down

(1) not part of the certified energy balance, missing BoPC shall be accounted for using the methods laid down in point 7.5

(2) according to manufacturer specification which shall ensure real world like operation

(3) if applicable/mounted on FCS respectively vehicle

(4) only adaptions are allowed to enable standalone operation

(5) integration of items is optional

(6) may be part of either TMS or WTS

7.2.4 Description of specific BoPCs

The TMS and the cooling sub-system may consist of multiple coolant circuits. All those circuits may be divided into an inner and outer part.

7.2.4.1 Inner part of the cooling circuit

Inner part of the cooling circuit consists of all parts of the cooling circuit that are integrated into the FCS and are part of the TMS of the UUT.

7.2.4.2 Outer part of the cooling circuit

All parts of the cooling sub-system that are not part of the UUT are referred to as the outer cooling sub-system, including the heat exchangers that are integrated into the vehicle chassis and might vary dependent on the vehicle type or other parts that are not part of the UUT.

7.3. Test procedure

7.3.1 Purpose

The purpose of the certification test procedure is to validate performance and capabilities declared by the manufacturer of the FCS, and to measure the fuel consumption / hydrogen mass flow under certain well-defined operating conditions. The aim is to generate reproducible data, suitable as input data for the simulation tool to enable the fuel consumption prediction of the certified vehicle component FCS.

7.3.2 Operation parameters and operating points

The parameters set out in table 10 shall apply for the purposes of the certification test.

Table 10

Operation Parameters and Operating Points

Name / Description	**Mandatory: Y/N**	**Unit**
SCOP	Y	kW
relative transition slope for set-point ramp-up (RTS-UP) The manufacturer may specify a value for RTS-UP. If no value is specified the default value in accordance with point 7.3.4.6 shall be used.	N	s-1
relative transition slope for set-point ramp-down (RTS-DOWN) The manufacturer may specify a value for RTS-DOWN. If no value is specified the default value in accordance with point 7.3.4.6 shall be used.	N	s-1
operating points: #01 .. #n_{op} OP01, lower electrical power-output of FCS at OP #$_{01}$, OPn_{op} or OP@n_{op} upper operating point. One row in the table per point. To indicate if OPxx is tested during ramp-up or ramp-down, an additional suffix in form of one character shall be added in the information documents, which shall be letter ‘a’ for ascending operating points, and letter ‘d’ for descending operating points.	Y	kW
FCS Type A/C (PCS part of UUT): Lower voltage level of PCS output $U_{PCS, out, lower}$ at which the FCS can be operated at OP@n_{op} without current limitation. FCS Type B/D (PCS not part of UUT): $U_{PCS, lower}$ is a DC/DC-requirement specification provided by the manufacturer. The test cell DC/DC shall meet this requirement.	Y	V
FCS Type A/C (PCS part of UUT): Upper voltage level of PCS output $U_{PCS, out, upper}$ at which the FCS can be operated at OP@n_{op}. FCS Type B/D (PCS not part of UUT): $U_{PCS, upper}$ is a DC/DC-requirement specification provided by the manufacturer. The test cell DC/DC shall meet this requirement.	Y	V

7.3.3 Methodology

The certification test procedure aims to record static data on a stabilized FCS at a certain number of different operating points. Each operating point shall be specified by its set-point for the electrical FCS power output.

During the certification, the FCS shall be operated in its standard operation conditions, as documented by the manufacturer in accordance with Appendix 7.

The voltage level at the interface between the PCS and the external electric components shall be determined by the lower and upper voltage level as specified in Table 10 to:

$U_{PCS, out} = 0.5 * (U_{PCS, out, upper} + U_{PCS, out, lower})$

In case the PCS is not included in the UUT, $U_{PCS, upper}$ and $U_{PCS, lower}$ shall be derived from the requirement specifications for the DC/DC converter as provided by the manufacturer.

The manufacturer shall declare in accordance with Appendix 7 realistic boundary conditions for normal operation of the FCS for in-vehicle usage.

7.3.4 Test procedure description

The entire test procedure shall be performed without interruption and the entire test shall be recorded.

The manufacturer shall specify the operating point (OP) with the lowest (OP01) and highest (OPn_{op}) electrical FCS power output to be measured as certification test range. That range shall cover the whole span for real world operation in vehicle application.

7.3.4.1 Definition of operating points

The FCS shall be tested on a defined number of OPs, n_{op}, which shall be equal or greater than 12.

The OP with the lowest (OP01) and highest (OPn_{op}) electrical FCS power output shall be measured mandatorily.

The remaining number of OP shall be distributed within the certification test range. The distribution of OPs does not need to be equidistant but shall enable a good interpolation of the fuel consumption over the whole certification test range. In regions of elevated non-linear relationship between FCS power output and fuel consumption a smaller step size between set-points is allowed.

The naming convention of the operation set-points shall be defined as:

P@OP01: target electrical FCS power output at OP01

P@OPxx: target electrical FCS power output at any OP between lowest and highest with the identifier xx running from 02 to (n_{op} -1)

P@OPn_{op}: target electrical FCS power output at OPn_{op}

The maximum step size between two adjacent OPs, Step-size$_{max}$, shall be defined in accordance with the following equation:

$\text{Step-size}_{max} < 0,20 * (P@OPn_{op} – P@OP01)$

7.3.4.2 Conditioning phase

Prior to the actual test the system shall be operated at least 60 minutes at a SCOP. That set-point (electrical FCS power output target value) shall lie between 40 % and 60 % of the upper operating point for certification, OPn_{op}, and shall be defined by the manufacturer.

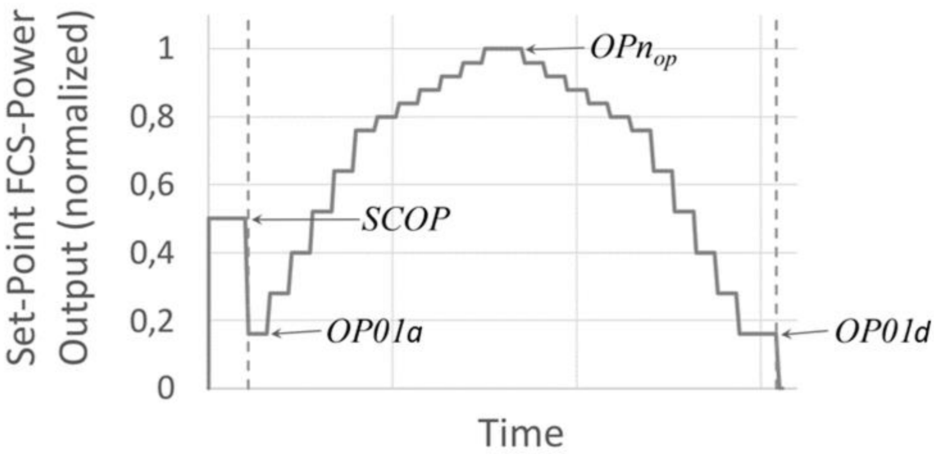
7.3.4.3 Sequence of operating points

The series shall start from OP01 and shall be continued in ascending order up to OPn_{op} and then back again to the lowest OP in descending order. The entire duration is dependent on the stabilization time at the individual OPs.

Figure 3 depicts the whole test sequence in a schematic manner.

Figure 3

Sequence of OP



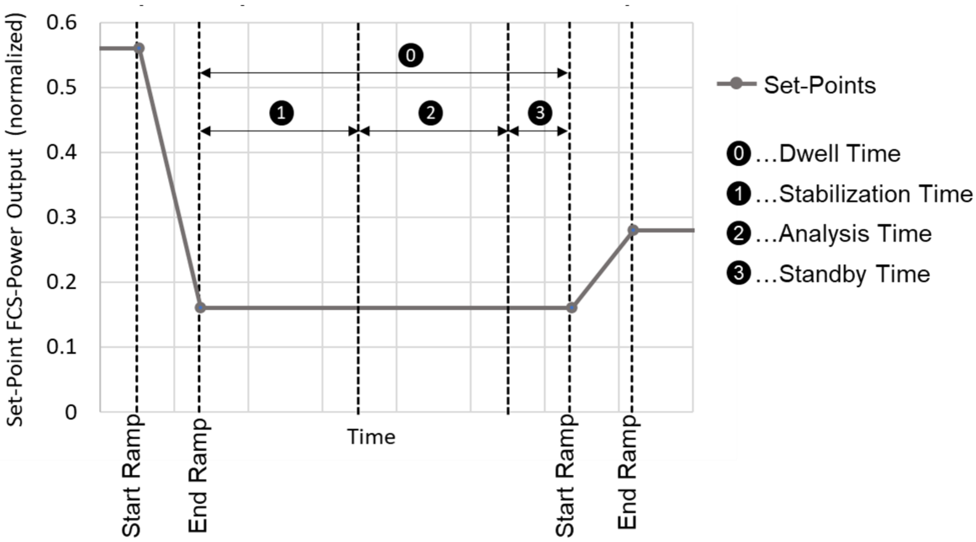
7.3.4.4 Steps to be performed at each operating point

In order to determine the fuel consumption at each OP in a reproducible manner, a sufficient stabilization time at each OP shall be defined by the manufacturer to achieve adequate stability of the system. The stabilization time shall be defined as individual value for each OP to be measured and shall be between $t_{stab,min}$ = 300 - 1 s and $t_{stab,max}$ = 1800 + 1 s. Both stabilization times for the same OP in the ascending and descending part shall be within a tolerance of 2 seconds. The stabilization time for a measured OP shall start immediately after the ramp from the previous setpoint is completed. The analysis time is required to gain average values avoiding measurement noises and other instationary effects. Therefore, the analysis time shall be set to t_{anlys} = 180 ± 1 s and shall start after the stabilization time. The measured values within that time span shall fulfil the stability criteria set out in point 7.3.4.5 unless the maximum stabilization time of $t_{stab,max}$ = 1800 + 1 s is applied. After the analysis time, the standby time used for a proper separation from the next load point shall follow and the duration shall be defined as t_{stb} = 10 ± 1 s.

Figure 4 depicts the steps to be performed at each OP.

Figure 4

Steps to be performed at each OP



7.3.4.5 Stability Criteria

To determine the degree of steadiness of the fuel consumption, metered by means of a test cell sensor at the fuel inlet of the FCS ($\dot{m}_F$ FPS as specified in Figure 5), a least squares linear regression shall be performed, the independent variable being the time and the dependent variable being the fuel flow, in accordance with points 7.3.6.1 and 7.3.6.2. Based on the regression analysis, the following two stability indicators shall be calculated in accordance with point 7.3.6.3:

(a) absolute value of the relative slope of the estimate (ARS), which represents the slope;

(b) relative error of estimate (REE), which represents the degree of fluctuations of the monitored item.

The values for the stability criteria shall be calculated in accordance with point 7.3.6.3. The OP shall be considered as stable if both indicators are below a specific threshold value within the defined analysis time frame. The threshold values for both stabilization indicators ARS and REE shall be calculated in accordance with the threshold values set out in table 11. For the calculation of the REE, the normalized set power at any OP compared to the highest OP shall be defined as:

$$P@OPxx_{norm} = \frac{P@OPxx}{P@OPn_{op}}$$

Table 11

Threshold values

Indicator:	**Threshold Value:**
ARS	7,0E-5 sE-1
REE	$\frac{1}{P@OPxx_{norm}} + 1$

In case the proof of stability at any OP fails, the test shall be repeated with an enlarged or the maximum stabilization time in accordance with point 7.3.4.4.

7.3.4.6 Transition slope between two operating points

The transition from one set-point to the next shall be executed with a moderate slope. Suitable slopes for up- and down-ramping of the set-point shall be specified by the manufacturer. The objective shall be to set a slope that facilitates a quick stabilization on the subsequent operating point. No restrictions shall apply to the value of the transition slope or to the shape of that slope. In case no transition slope is specified by the manufacturer, the RTS shall be set to +0.002 ±0.0004 s^{-1} during ramp-up and -0.002 ±0.0004 s^{-1}during ramp-down.

$$RTS = \frac{dP_{el}/dt}{P@OPn_{op}}$$

where:

P_{el}: electrical DC power output of the FCS

dP_{el}/dt: slope of the transition of one operating point $P_{el,\,1}$ at time t_1 to a following operating point $P_{el,\,2}$ at time t_2. Where the transition time $dt = t_2 - t_1$ is small enough to neglect the effects of non-linearity

$P@OPn_{op}$: target electrical FCS power output at highest OP

7.3.4.7 Calculation of measured fuel consumption and power output

The electric power output and the corresponding hydrogen consumption rate of the UUT at each individual OP shall be calculated as the arithmetic mean over the analysis time t_{anlys} defined in accordance with point 7.3.4.4. The calculation of the arithmetic means shall be done as follows:

$$P_{FCS,avg,p} = \frac{1}{n}\sum_{i\,=\,1}^{n} P_{FCS,\,i,p}$$

and

$$\dot{m}_{F,avg,p} = \frac{1}{n}\sum_{i\,=\,1}^{n} \dot{m}_{F,\,i,p}$$

where:

$P_{FCS,avg,p}$: arithmetic mean over n recorded values within t_{anlys} of the electrical power output $P_{FCS,\,i,p}$ in kW

$P_{FCS,\,i,p}$: recorded value of electrical power output with index number i in kW.

This power output is metered UUT-type dependent after the PDS (sensor position: P_el, PDS, as depicted in Figure 5) or PCS (sensor position: P_el, PCS as set out in point 7.4, figure 5)

$\dot{m}_{F,avg,p}$: arithmetic mean over n recorded values within t_{anlys} of the fuel flow $\dot{m}_{F,i,p}$ in g/h

$\dot{m}_{F,i,p}$: recorded value of fuel flow with index number i in g/h

i Index of individual recorded data point 1 to n

p Index for ascending (a) or descending (d) path (omitted for OPn_{op})

n: number of recorded values during the averaging period t_{anlys} defined in accordance with point 7.3.4.4.

Subsequently, one resulting arithmetic mean for both values $P_{FCS,\ avg}$ and $\dot{m}_{F,\ avg}$ for each individual OP below OP@n_{op} shall be calculated as the arithmetic mean of the averaged values from the ascending and descending part in accordance with the following equations:

$$P_{FCS,\ avg} = \frac{P_{FCS,\ avg,a} + P_{FCS,avg,d}}{2}$$

and

$$\dot{m}_{F,\ avg} = \frac{\dot{m}_{F,\ avg,a} + \dot{m}_{F,avg,d}}{2}$$

where:

$P_{FCS,\ avg,a}$:	arithmetic mean of the electrical power output during the ascending path determined in accordance with the preceding paragraph in kW
$P_{FCS,\ avg,d}$:	arithmetic mean of the electrical power output during the descending path determined in accordance with the preceding paragraph in kW
$\dot{m}_{F,\ avg,a}$:	arithmetic mean of the fuel flow during the ascending path determined in accordance with the preceding paragraph in g/h
$\dot{m}_{F,\ avg,d}$:	arithmetic mean of the fuel flow during the descending path determined in accordance with the preceding paragraph in g/h.

For the OPn_{op} (upper OP), the values for $P_{FCS,\ avg}$ and $\dot{m}_{F,\ avg}$ shall be set to the corresponding values of $P_{FCS,\ avg,p}$ and $\dot{m}_{F,\ avg,p}$ from the previous evaluation step since for this OP only one single measurement exists.

7.3.4.8 Correction of the FCS power output to reference conditions

The measured FCS power output P_{FCS} shall be corrected in accordance with the following equation:

$$P^*_{FCS} = P_{FCS,avg} + \Delta\eta\ \dot{m}_{F,avg}\ \frac{NCV_{std,H2}}{3600\frac{s}{h}}$$

with:

$$\Delta\eta = k_{load} * (p_{in} - p^*)$$

where:

P^*_{FCS} :	Electrical power output of FCS at reference conditions in kW
$P_{FCS,avg}$:	Electrical power output of FCS in accordance with point 7.3.4.7 in kW
$\dot{m}_{F,avg}$:	Fuel flow in accordance with point 7.3.4.7 in g/h
$NCV_{std,H2}$:	Standard net calorific value of hydrogen in accordance with point 5.3.3.1 in MJ/kg
p^* :	Pressure at reference conditions with the numerical value of 0,975 bar

p_{in} : Pressure of intake air to the APS of the UUT ($p_{A,APS}$ as specified in Figure 5) in bar

K_{load} : Gradient of efficiency determined in accordance with point 7.3.4.8.1 in bar^{-1}.

7.3.4.8.1 Gradient of efficiency k_{load}

The value of normalized power shall be determined by dividing the value of $P_{FCS,avg}$ of a specific OP by the value of $P_{FCS,avg}$ for OPn_{op}, both derived in accordance with point 7.3.4.7.

Based on the value of normalized power of a specific OP, the value of k_{load} shall be determined from the corresponding data in table 12 by means of linear interpolation between the two adjacent data points. In case the value of normalized power is lower than 0,1, the value of k_{load} defined at 0,1 normalized power shall be used.

Table 12

Parameter k_{load} as function of normalized power

Normalized power [-]	k_{load}
0,1	0,3730
0,2	0,1485
0,5	0,0745
0,8	0,0855
1,0	0,1115

7.3.5 Test Conditions

The ambient conditions in the test cell shall fulfil the minimum and maximum criteria set out in table 13.

Table 13

Ambient and media condition limits during certification test

	min value:	max value:
Ambient pressure	90,0 kPa	102,0 kPa
Ambient temperature	288,0 K	298,0 K
Oxidant (air) inlet pressure	90,0 kPa	102,0 kPa
Oxidant (air) inlet temperature	288,0 K	303,0 K
Relative Humidity, Oxidant (air) supply	45,0 %	80,0 %

7.3.6 Statistics

7.3.6.1 Mean value and standard deviation

The arithmetic mean value shall be calculated as follows:

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n}$$

The standard deviation shall be calculated as follows:

$$s = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}}$$

7.3.6.2 Regression analysis

The slope of the regression shall be calculated as follows:

$$a_1 = \frac{\sum_{i=1}^{n}(y_i - \bar{y}) \times (x_i - \bar{x})}{\sum_{i=1}^{n}(x_i - \bar{x})^2}$$

The y intercept of the regression shall be calculated as follows:

$$a_0 = \bar{y} - (a_1 \times \bar{x})$$

The standard error of estimate shall be calculated as follows:

$$SEE = \sqrt{\frac{\sum_{i=1}^{n}[y_i - (x_i \cdot a_1 + a_0)]^2}{n}}$$

7.3.6.3 Stability criteria

The ARS shall be calculated as follows:

$$ARS = \left|\frac{a_1}{\bar{y}}\right|$$

The REE value shall be calculated as follows:

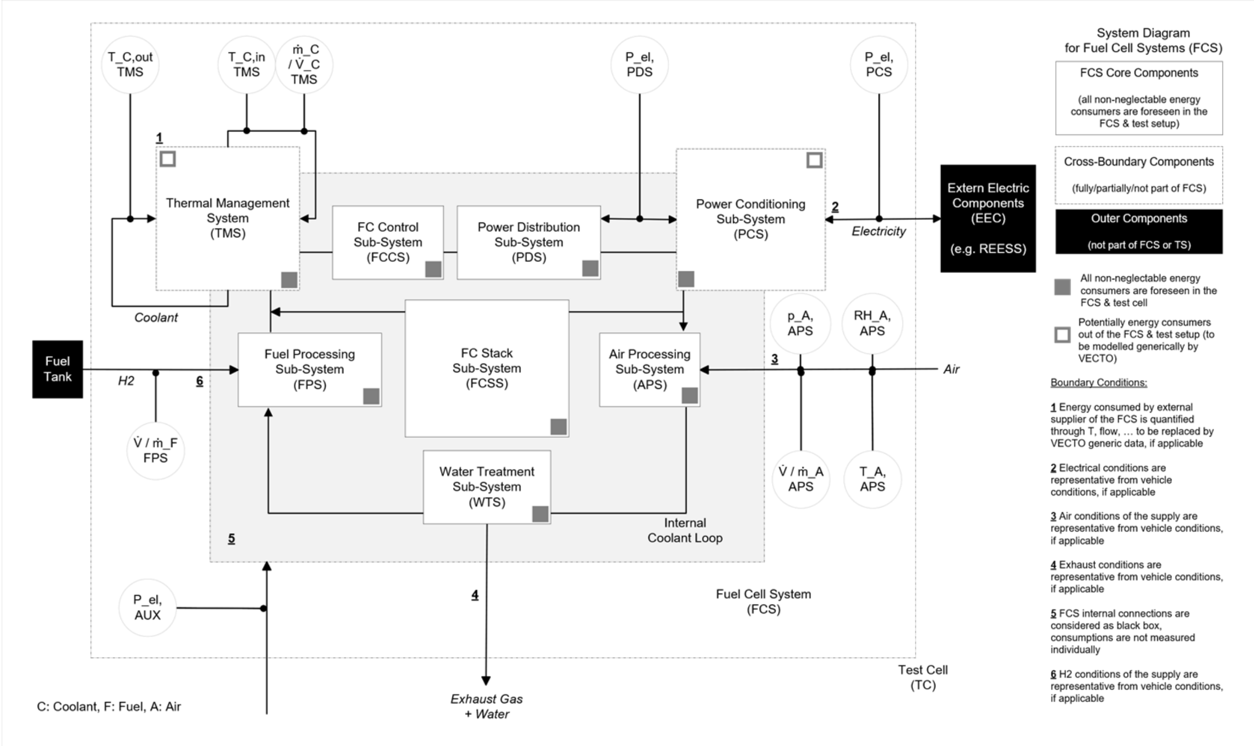
$$REE = \left|\frac{SEE}{\bar{y}}\right| \cdot 100\ \%$$

7.4. Certification test documentation

The relevant data for test reproducibility shall be documented in the information document set out in Appendix 7. The position of different sensors used for testing shall be defined in accordance with the schematic sketch of a representative FCS set out in figure 5.

Figure 5

Schematic sketch of a representative FCS including the position of relevant sensors



7.5 Calculation of effective electrical power output

The electrical power output of fuel cell system at reference conditions, P^{*}_{FCS}, determined in accordance with point 7.3.4.8 shall be corrected for the following configurations:

(a) PCS not being part of the FCS installed for the certification test;

(b) power consuming balance of plant components not installed for the certification test at all or not installed within the UUT or being externally powered by the test bed infrastructure during the certification test.

7.5.1 Recording of additional values

For each coolant pump not installed for the certification test at all or not installed within the UUT the following values shall be recorded separately:

- $\dot{V}_{C,TMS,in}$ volume flow of the coolant upstream of the TMS;
- $p_{C,TMS,in}$ pressure of the coolant upstream of the TMS;
- $p_{C,TMS,out}$ pressure of the coolant downstream of the TMS.

For each power consuming balance of plant component being externally powered by the test bed infrastructure during the certification test the electrical power uptake, $P_{el,AUX}$, shall be recorded separately.

In accordance with point 3.2.2 the volume flow and the electrical power uptake shall have a positive algebraic sign.

All recorded values shall be averaged for each individual operating point of the FCS measured in accordance with the method set out in point 7.3.4.7 by applying the same specific averaging period t_{anlys} in accordance with point 7.3.4.4.

7.5.2 Equations for corrections performed

All following equations shall be evaluated for each individual operating point of the FCS measured in accordance with the method set out in point 7.3.4.7.

In case the PCS not being part of the FCS installed for the certification test, the measured electrical power output at the location PDS in accordance with the schematic sketch of a representative FCS set out in figure 5 shall be corrected for the losses of a generic PCS in accordance with the following equation:

$P^*_{el,PCS} = P^*_{FCS,PDS} \text{ x } eta_{DC/DC}$

where:

$P^*_{el,PCS}$	electrical power output at the location PCS in accordance with Figure 5 at reference conditions in kW
$P^*_{FCS,PDS}$	electrical power output of fuel cell system at the location PDS in accordance with the schematic sketch of a representative FCS set out in figure 5 at reference conditions determined in accordance with point 7.3.4.8 in kW
$eta_{DC/DC}$	generic efficiency factor of DC/DC converter shall be 0.975

For each coolant pump not installed for the certification test at all or not installed within the UUT the electrical power uptake shall be calculated in accordance with the following equation:

$P_{el,Cool} = (p_{C,TMS,in} - p_{C,TMS,out}) \text{ x } \dot{V}_{C,TMS,in} / eta_{WP,hyd} / eta_{WP,EM}$

where:

$P_{el,Cool}$	electrical power uptake of the coolant pump in kW
$p_{C,TMS,in}$	pressure of the coolant upstream of the TMS in kPa
$p_{C,TMS,out}$	pressure of the coolant downstream of the TMS in kPa
$\dot{V}$C,TMS,in	volumetric coolant flow upstream of the TMS in m3/s
etaWP,hyd	generic hydraulic efficiency factor of pump shall be 0,8
etaWP,EM	generic efficiency factor of electric pump drive shall be 0,8.

The final effective electrical power output of FCS used as input to the simulation tool taking all components consuming additional electric power into account shall be calculated in accordance with the following equation:

$$P^*_{el,FCS,net} = P^*_{el,PCS} + \sum_{i=1}^{n} P_{el,AUX,i} \; / \; eta_{DC/DC} + \sum_{j=1}^{o} P_{el,AUX,j} + \sum_{k=1}^{p} P_{el,Cool,k} \; / \; eta_{DC/DC} + \sum_{l=1}^{q} P_{el,Cool,l}$$

where:

$P^*_{el,FCS,net}$	effective electrical power output of FCS (used as input to the simulation tool) at reference conditions in kW
$P^*_{el,PCS}$	electrical power output at the location PCS in accordance with Figure 5 at reference conditions in kW
$P_{el,AUX}$	electrical power uptake of balance of plant component not installed for the certification test at all or not installed within the UUT or being

externally powered by the test bed infrastructure during the certification test in kW

where the following differentiation shall be applied:

$P_{el,AUX,i}$ all components connected to the FCS either at the location PDS in accordance with Figure 5 or via a separate DC/DC converter; where i = 1, 2, 3, … maximum number n of such components to be considered

$P_{el,AUX,j}$ all components connected to the FCS either at the location PCS in accordance with Figure 5 or without a separate DC/DC converter; where j = 1, 2, 3, … maximum number o of such components to be considered

$P_{el,Cool}$ electrical power uptake of the coolant pump in kW

where the following differentiation shall be applied:

$P_{el,Cool,k}$ all coolant pumps connected to the FCS either at the location PDS in accordance with Figure 5 or via a separate DC/DC converter; where k = 1, 2, 3, … maximum number p of such components to be considered

$P_{el,Cool,l}$ all coolant pumps connected to the FCS either at the location PCS in accordance with Figure 5 or without a separate DC/DC converter; where l = 1, 2, 3, … maximum number q of such components to be considered

$eta_{DC/DC}$ generic efficiency factor of DC/DC converter shall be 0,975.

7.5.3 Input to the simulation tool

The values of effective electrical power output $P^{*}_{el,FCS,net}$ determined in accordance with point 7.5.2 multiplied by -1 and absolute values of the fuel flow determined in accordance with point 7.3.4.7 shall be used as input to the simulation tool.”;

(18) Appendix 7 is replaced by the following:

‘*Appendix 7*

Information document for FCS

Communication concerning:	Administration stamp
– granting[1] – extension[1] – refusal[1] – withdrawal[1]	

[1]delete if not applicable

of a certificate on CO_2 emission and fuel consumption related properties of an electric machine system IEPC / IHPC Type 1 / battery system / capacitor system in accordance / FCS / with Commission Regulation (EU) 2017/2400.

Commission Regulation (EU) 2017/2400 as applicable on [date]

Certification number:

Hash:

Reason for extension:

Information document No:	Issue:
	Date of issue:
	Date of Amendment:

pursuant to …

FCS type / family (if applicable):

0. GENERAL

0.1. Name and address of manufacturer:

0.2. Make (trade name of manufacturer):

0.3. FCS type:

0.4. FCS family:

0.5. FCS type as separate technical unit / FCS family as separate technical unit:

0.6. Commercial names (if available):

0.7. Means of identification of model, if marked on the FCS:

0.8. In the case of components and separate technical units, location and method of affixing of the EC approval mark:

0.9. Names and addresses of assembly plants:

0.10. Name and address of the manufacturer's representative:

PART 1

ESSENTIAL CHARACTERISTICS OF THE (PARENT) FCS AND THE FCS TYPES WITHIN A FCS FAMILY

	Parent FCS or FCS type	Family members			
		#1	#2	#3	…

1. General:

1.1. Upper power of FCS (specified upper electric power in real world operation): .... kW

1.2. Weight of FCS (including all parts of UUT): .... kg

1.3. Gross outer dimension of FCS (length, width and height): .... mm

1.4. U_{out} range at the UUT interface, either PDS, out or PCS, out (min/max): V

1.5. I_{out} range at the UUT interface, either PDS, out or PCS, out (min/max):.................... A

1.6. Output voltage range of PCS (min/max)(*)[*footnote*]: V

1.7. Type of FCS regarding test setup(**) [*footnote*](A, B, C, D): ....

2. APS:

2.1. Air Compressor

2.1.1. Make(s), type(s)..

(*) if applicable

(**) In accordance with point 7.2.1 and table 9 of this Annex

2.1.2. Power uptake in certification test range (min/max).. kW

2.2. Air humidification device(*)

2.2.1. Make(s), type(s):..

2.2.2. Humidity exchange membrane, make(s), type(s): ....

3. TMS:

3.1. Cooling media of inner cooling liquid

3.1.1. Make(s), type(s) ....

3.1.2. Specific heat capacity @345 K: .... J/(kg·K)

3.1.3. Density @345 K: .... kg/l

4. WTS:

4.1. Deionization unit

4.1.1. Make(s), type(s) ....

4.1.2. Ion-conductivity cooling media (nominal/max) .... mS/cm

5. FPS:

5.1. Fuel injector or combination of injector/ejector:

5.1.1. Make(s), type(s):..

5.1.2. Number of injectors: ....

5.2. Anode recirculation blower(*) ....

5.2.1. Make(s), type(s)(*):...

6. FCSS:

6.1. FC Stack(s):

6.1.1. Make(s), type(s):..

6.1.2. Number of stacks:...

6.1.3. Cell number of each stack: ....

6.1.4. Cell surface area of each stack: .... cm²

6.1.5. Set point of reference stack current: .... A

6.1.6. Reference condition(***), temperature $T_{FCSS} = 0.5 \times \left(T_{C,out,\,FCSS} + T_{C,\,in,\,FCSS}\right)$: … K

6.1.7. Reference condition(***), pressure $p_{A,\,FCSS,\,in}$:.. kPa

6.1.8. Reference condition(***), anode stoichiometry ν_{fuel}..

6.1.9. Reference condition(***), cathode stoichiometry ν_{Air} ....

6.1.10. Stack voltage at reference condition of each stack:.. V

6.1.11. Make(s), Type(s) of membrane electrode assemblies (MEA):............................

7. Power Distribution Sub-System (PDS):

7.1. Power plug at the interface to FCSS(*)

7.1.1. Make(s), type(s):..

8. Power Conditioning Sub-System (PCS):

8.1. DC/DC(*)

8.1.1. Make(s), type(s): ....

8.1.2. Voltage range inlet / primary side (min/max): V

8.1.3. Voltage range inlet / secondary side (min/max): V

9. Fuel Cell Control Sub-System:

9.1. Firmware, Version & Build Number: ....

9.2. Control Unit Hardware, Make & Type: ....

LIST OF ATTACHMENTS

No:	Description:	Date of issue:
1	Information on FCS test conditions	DD-MMM-YYYY
2	Information on operation boundary conditions	DD-MMM-YYYY
3	Information on FCS certification test results	DD-MMM-YYYY

Attachment 1 to FCS information document

Information on FCS test conditions:

	value and unit:
Ambient pressure (absolute)	XYZ.0 kPa
Ambient temperature	XYZ.0 K
Oxidant (Air) inlet temperature	XYZ.0 K
Oxidant (Air) inlet pressure (absolute)	XYZ.0 kPa
Relative Humidity, oxidant / air supply	XY.0 %
Cooling media of inner circuit: Make: ___________, Type: ______________	
Density of cooling media of inner circuit @345 K	XY.0 kg/l
Specific heat capacity of cooling media in the inner cooling circuit @345 K	XYZ.0 J/(kg·K)
SCOP:	XYZ.0 kW
Operating point #01 (OP01):	XYZ.0 kW
Operating point #02 (OP02):	XYZ.0 kW
Operating point #xx (OPxx, OP between OP02 and OP@n_{op}):	XYZ.0 kW
Operating point #n_{op} (OP@n_{op}, highest operating point):	XYZ.0 kW
FCS Type A/C (PCS part of UUT): Lower voltage level of PCS output $U_{PCS,out,lower}$ at which the FCS can be operated at OP@n_{op} without current limitation. FCS Type B/D (PCS not part of UUT): $U_{PCS, lower}$ is a DC/DC-requirement specification	XYZ.0 V
FCS Type A/C (PCS part of UUT): Upper voltage level of PCS output $U_{PCS,out,upper}$ at which the FCS can be operated at OP@n_{op}. FCS Type B/D (PCS not part of UUT): $U_{PCS, upper}$ is a DC/DC-requirement specification	XYZ.0 V
Optional, operation condition related parameters:	

relative transition slope for set-point ramp-up (RTS-UP) (it is an approximate value for orientation, the manufacturer may specify a range around this number)	XYZ.0	s^{-1}
relative transition slope for set-point ramp-down (RTS-DOWN) (it is an approximate value for orientation, the manufacturer may specify a range around this number)	XYZ.0	s^{-1}

Attachment 2 to FCS information document

Boundary conditions for FCS operation in vehicles as declared by the manufacturer:

This table is adopted / completed by the manufacturer according to their operation specification for FCS operation inside a vehicle. The specifications in the following table are mandatory:

OP#	parameter	lower	upper:
01	Ambient Temperature	XYZ.0 K	XYZ.0 K
…		XYZ.0 K	XYZ.0 K
n_{op}		XYZ.0 K	XYZ.0 K
01	Ambient Pressure	XYZ.0 Pa	XYZ.0 Pa
…		XYZ.0 Pa	XYZ.0 Pa
n_{op}		XYZ.0 Pa	XYZ.0 Pa
01	Ambient Humidity	XYZ.0 %	XYZ.0 %
…		XYZ.0 %	XYZ.0 %
n_{op}		XYZ.0 %	XYZ.0 %
01	Cooling Liquid Temperature FCSS Inlet Label according to Figure 5: T_C,in with the additional suffix FCSS	XYZ.0 K	XYZ.0 K
…		XYZ.0 K	XYZ.0 K
n_{op}		XYZ.0 K	XYZ.0 K
01	Cooling Liquid Temperature FCSS Outlet	XYZ.0 K	XYZ.0 K
…		XYZ.0 K	XYZ.0 K
n_{op}		XYZ.0 K	XYZ.0 K
01	Further boundary conditions for operation inside a vehicle	XYZ.0 Unit	XYZ.0 Unit
…		XYZ.0 Unit	XYZ.0 Unit
n_{op}		XYZ.0 Unit	XYZ.0 Unit

Attachment 3 to FCS information document

Table 1

Information on FCS certification test results in form of arithmetic mean values

OPXXa: ascending OPXXd: descending	01: Duration / s	02: ARS / s^{-1}	03: REE / -	04: SP el. power demand for FCS at the interface PDS/PCS(*) / kW	05: SP DC current of FCS at the interface PDS/PCS(*)/ A	06: PV el. power output of the FCS at the UUT interface (i.e. either PDS or PCS) / kW	07: PV DC current at the interface UUT interface (i.e. either PDS or PCS) / A	reserved	09: PV voltage at the UUT interface (i.e. either PDS or PCS) / V	10: Mass flow of fuel / g/h	…
SCOP											
OP01a											
OP02a											
OP03a											
OP..											
OPn_{op} (***)											
OPn_{op}-1d											
OPn_{op}-2d											
OPn_{op}-3d											
OP..d											
OP01d											

OPXXa: ascending **OPXXd: descending**	11: Volume flow of fuel (**) / l/min	12: Fuel pressure at FCS inlet / kPa	13: Fuel pressure at FCSS inlet (*) / kPa	14: Fuel temperature at FCSS inlet (*) / K	15: Mass flow of air / g/h	16: Volume flow of air (**) / l/min	17: Air pressure at APS inlet / kPa	18: Air temperature at APS inlet / K	19: Air relative humidity at APS inlet / %	20: Mass flow of cooling media at TMS inlet / g/h	…
SCOP											
OP01a											
OP02a											
OP03a											
OP..											
OP*n* $_{op}$ (***)											
OP n_{op}**-*1d***											
OP n_{op}**-*2d***											
OP n_{op}**-*3d***											
OP..d											
OP01d											

OPXXa: ascending **OPXXd: descending**	21: Volume flow of cooling media at TMS inlet (**) / l/h	22: Temperature of cooling media at TMS inlet / K	23: Temperature of cooling media at TMS outlet / K	24: Electric power provided to the FCS from the test cell / kW
SCOP				
OP01a				
OP02a				
OP03a				
OP..				
OP*n* $_{op}$ (***)				
OP n_{op}**-1d**				
OP n_{op}**-2d**				
OP n_{op}**-3d**				
OP..d				
OP01d				

(*) if applicable / accessible

(**) if mass flow of media needs to be calculated based on volume flow and density

(***) n_{op}: number of different operating points, OP@n_{op} is the upper OP during certification as specified in point 7.3.4.1

Explanations regarding the table in attachment 3 to FCS information document

The positions of sensors are specified in a schematic manner in figure 5. All values - except for the duration, ARS and REE - are arithmetic mean values at each OP determined over the analysis time, t_{anlys}, defined in accordance with point 7.3.4.4 (i.e. before the averaging step of ascending and descending). For the SCOP the averaging time frame shall be the defined by the same time frame length as for the analysis time and shall be located just before the transition to the subsequent OP01a.

The minimum precision requirements of sensors are indicated by a type classification in the respective column in table 2. The following types are distinguished where type I has the highest precision and type III the lowest:

Type I: accuracy according to table 1 of this Annex;

Type II: accuracy of integrated and accessible sensors (i.e. all FCS integrated automotive sensors are of type II);

Type III: not applicable or precision not specified: precision according to best practice / common sense.

If the same value is measured by more than one sensor only the numbers determined by the sensor with the higher precision shall be documented. If in the comment column the phrases "if applicable" / "if accessible" are set out, no additional sensors need to be installed.

Table 2

Accuracy requirements of sensors

#:	Description:	Unit:	Type:	Comment:
01	Duration	s	III	time period in between transition periods of the power/current set point
02	ARS	s^{-1}	III	refer to point 7.3.4.5 of this Annex: Absolute value of the Relative Slope
03	REE	-	III	refer to point 7.3.4.5 of this Annex: Relative error of estimate
04	SP el. power demand for FCS at the UUT interface	kW	III	set point, if applicable (variant dependent: either PDS,out or PCS,out) (in case P_{el} is a SP)
05	SP DC current of FCS at the UUT interface	A	III	set point, if applicable (variant dependent: either PDS,out or PCS,out) (in case I_{FCS} is a SP)
06	PV el. power output of the FCS at the UUT interface	kW	I	process value, (variant dependent: either PDS,out or PCS,out) label in Figure 5: P_el, PDS or P_el,PCS if not metered directly, but calculated on the basis of U and I values, the U and I sensors shall comply with sensors type I
07	PV DC current at the UUT interface	A	I	process value (variant dependent: either PDS,out or PCS,out)
08	reserved			
09	PV voltage at the UUT interface	V	I	process value (variant dependent: either PDS,out or PCS,out)
10	Mass flow of fuel	g/h	I/III	either measured or calculated via density and volume flow, label in Figure 5: ṁ_F, FPS

#:	Description:	Unit:	Type:	Comment:
11	Volume flow of fuel	l/min	I/III	if mass flow of media needs to be calculated based on volume flow and density otherwise it can be omitted, label in Figure 5: $\dot{V}$_F, FPS
12	Fuel pressure at FCS inlet	kPa	I	at interface test cell / UUT
13	Fuel pressure at FCSS inlet	kPa	II	if accessible
14	Fuel temperature at FCSS inlet	K	II	if accessible, else fuel temperature at the FCS inlet
15	Mass flow of air	g/h	I	either measured or calculated via density and volume flow (label in Figure 5: $\dot{m}$_A, APS)
16	Volume flow of air	l/min	I	if mass flow of media needs to be calculated based on volume flow and density otherwise it can be omitted (label in Figure 5: $\dot{V}$_A, APS)
17	Air pressure at APS inlet	kPa	I	label in Figure 5: p_A, APS
18	Air temperature at APS inlet	K	I	label in Figure 5: T_A, APS
19	Air relative humidity at APS inlet	%	II	relative humidity at FCS inlet / FCS/APS interface; label in Figure 5: RH_A
20	Mass flow of cooling media at TMS	g/h	II	if not metered, it is calculated via volume flow and density, label in Figure 5: $\dot{m}$_C, TMS
21	Volume flow of cooling media at TMS	l/h	II	if mass flow of media needs to be calculated based on volume flow and density otherwise it can be omitted label in Figure 5: $\dot{V}$_C, TMS
22	Temperature of cooling media at TMS inlet	K	II	label in Figure 5: T_C, in_TMS
23	Temperature of cooling media at TMS outlet	K	II	label in Figure 5: T_C, out_TMS
24	Electric power provided to the FCS from the test cell	kW	I	the sum of all electric power supplied from the test cell into the UUT (auxiliary power), label in Figure 5: P_el, AUX
	…			…
	…			*If other values are necessary in order to ensure a reproducibility of the test, those values shall be added as well including if the cooling is in multiple circuits, in which case each cooling flow shall be documented separately.*

’;

(19) Appendix 8 is amended as follows:

(a) the fifth indent is replaced by the following:

‘— Step 5: The overload characteristics shall be determined from the data generated in accordance with step 2. The overload torque and the corresponding rotational speed shall be calculated as average values over the speed range where the power is equal or greater than 90 % of the maximum power. In case the resulting overload torque is lower than continuous torque, the overload torque shall be set to the 30 minutes continuous torque resulting from step 4. The overload duration t0_maxP shall be defined by the whole duration of the test run performed in accordance with step 2 multiplied by a factor of 0,25.';

(b) in the sixth indent, point (e)(iii), the equation ' $P_{loss}(T_i, n_j) = \left(1 - n\left(\frac{T_i}{T_{max}}, \frac{n_j}{n_{rated}}\right)\right) \times |T_i| \times n_j \times \frac{2\pi}{60}$, is replaced by the following:

'$P_{loss}(T_i, n_j) = \left(1 - \eta\left(\frac{T_i}{T_{max}}, \frac{n_j}{n_{rated}}\right)\right) \times |T_i| \times n_j \times \frac{2\pi}{60}$';

(20) Appendix 9 is amended as follows:

(a) in point (2)(a), the equation '$T_{gbx,l,in}$ (n_{in}, T_{in}, gear) = T_{d0} + T_{d1000} × n_{in} / 1000 rpm + $f_{T,gear}$ × T_{in} 'is replaced by the following:

'$T_{gbx,l,in}$ (n_{in}, T_{in}, gear) = T_{d0} + T_{d1000} x n_{in} / 1000 rpm + $f_{T,gear}$ x $|T_{in}|$ ';

(b) in point (3)(a), the equation '$T_{diff,l,in}$ (T_{in}) = η_{diff} × $T_{diff,d0}$ / i_{diff} + (1- η_{diff}) × T_{in} ' is replaced by the following:

'$T_{diff,l,in}$ (T_{in}) = η_{diff} x $T_{diff,d0}$ / i_{diff} + (1 - η_{diff}) x $|T_{in}|$ ';

(21) Appendix 10 is amended as follows:

(a) point (1) is amended as follows:

(a) point (b) is replaced by the following:

'(b) The rated capacity shall be the value in Ah based on the capacity of single cells indicated on the datasheet from the cell manufacturer considering the arrangement of the single cells in parallel and series configuration. The resulting value for total capacity shall be multiplied by a factor of 0,9.';

(b) point (d) is replaced by the following:

'(d) The DCIR shall be determined in accordance with the following provisions:

(i) For HPBS in accordance with subpoint (a) the different values of DCIR shall be calculated by dividing the specific resistance of in [mOhm × Ah] as set out in the following table by the rated capacity in Ah as defined in accordance with subpoint (b) and multiplying the resulting value by the number of cells connected in series as indicated in accordance with Appendix 2, point 1.3.2, of Annex 6 –to UN Regulation No 100:

DCIR	Specific resistance in [mOhm × Ah]
DCIR R_{I2}	40
DCIR R_{I10}	45
DCIR R_{I20}	50

(ii) For HEBS in accordance with subpoint (a) the different values of DCIR shall be calculated by dividing the specific resistance in [mOhm × Ah] in the following table by the rated capacity in Ah as defined in accordance with subpoint (b) and multiplying the resulting value by the number of cells connected in series as indicated in accordance with Appendix 2, point 1.3.2, of Annex 6 to UN Regulation No 100:

DCIR	Specific resistance in [mOhm × Ah]
DCIR R_{I2}	210
DCIR R_{I10}	240
DCIR R_{I20}	270
DCIR R_{I120}	390

’;

(c) points (e)(i) and (e)(ii) are replaced by the following:

‘(i) For HPBS in accordance with subpoint (a) the values for maximum charging and maximum discharging current dependent on the SOC level shall be set to the respective current in A corresponding to the C-rates (nC) set out in the following table:

SOC [%]	C-rate (nC) for maximum charging current	C-rate (nC) for maximum discharging current
0	9,0	0,0
30	9,0	50,0
80	9,0	50,0
100	0,0	50,0

(ii) For HEBS in accordance with subpoint (a) the values for maximum charging and maximum discharging current dependent on the SOC level shall be set to the respective current in A corresponding to the C-rates (nC) set out in the following table:

SOC [%]	C-rate (nC) for maximum charging current	C-rate (nC) for maximum discharging current
0	0,9	0,0
30	0,9	5,0
80	0,9	5,0
100	0,0	5,0

’;

(b) point (2)(d) is replaced by the following:

‘The internal resistance shall be determined in accordance with the following equation:

$$R_{I,Cap} = R_{I,ref} \times \frac{V_{max,Cap} - V_{min,Cap}}{0.55 \times V_{ref}} \times \frac{C_{ref}}{C_{Cap}} \times \frac{1}{n_{ser}}$$

where:

$R_{I,Cap}$ = Internal resistance [Ohm]

$R_{I,ref}$ = Reference for internal resistance with a numeric value of 0,00375 [Ohm]

$V_{max,Cap}$ = Maximum voltage as defined in accordance with subpoint (b) above [V]

$V_{min,Cap}$ = Minimum voltage as defined in accordance with subpoint (c) above [V]

V_{ref} = Reference for maximum voltage with a numeric value of 2,7 [V]

C_{ref} = Reference for capacitance with a numeric value of 3000 [F]

C_{Cap} = Capacitance as defined in accordance with subpoint (a) above [F]

n_{ser} = number of cells connected in series as defined in accordance with subpoint (a) above [-]’;

(22) Appendix 11 is replaced by the following:

‘*Appendix 11*

Standard values for FCS

The following steps shall be performed to generate the input data for the FCS based on standard values:

(a) The input data for the FCS required in accordance with Appendix 15 shall be determined based on the maximum electrical power output of the FCS in accordance with Appendix 1, point 4.6., of Annex 6 to UN Regulation No 100.

(b) In case that more than one FCS are installed in the vehicle, the parameter in accordance with subpoint (a) shall be declared for each individual FCS separately and also the determination of input data shall be done for each individual FCS separately in accordance with the corresponding required input defined in table 11a of Annex III to this Regulation).

(c) The values of fuel mass flow as a function of electrical power output shall be calculated based on the generic efficiency values in accordance with the following table:

Normalized power [-]	**Efficiency [%]**
0,01	3,67
0,05	18,33
0,10	36,67
0,125	45,83
0,15	55,00
0,20	54,12
0,25	53,24
0,30	52,35
0,35	51,47
0,40	50,59
0,45	49,71
0,50	48,82
0,55	47,94
0,60	47,06
0,65	46,18
0,70	45,29
0,75	44,41
0,80	43,53
0,85	42,65
0,90	41,76
0,95	40,88
1,000	40,00

(d) The values of fuel mass flow and the corresponding electrical power output shall be determined in accordance with the following equation:

$$\dot{m}_{fuel} = P_{rated,el} * \frac{P_{norm,i}}{eta_i} * 100 * \frac{3600 \frac{s}{h}}{120 \frac{kJ}{g}}$$

where:

$\dot{m}_{fuel}$ = fuel mass flow [g/h]

$P_{rated,el}$ = maximum electrical power output of the FCS as defined in accordance with subpoint (a) above [kW]

$P_{norm,i}$ = normalized electrical power output of the FCS for all values i as defined in accordance with subpoint (c) above [-]

eta_i = efficiency of the FCS for all values i as defined in accordance with subpoint (c) above corresponding to $P_{norm,i}$ [%]

$NCV_{nstd,H2}$ = standard net calorific value of hydrogen in accordance with point 5.3.3.1 [MJ/kg]

$NCV_{std,H2}$: Standard net calorific value of hydrogen in accordance with point 5.3.3.1 in MJ/kg

$$P_{FCS,el,i} = P_{rated,el} * P_{norm,i}$$

where:

$P_{FCS,el,i}$ = electrical power output of the FCS [kW]

$P_{rated,el}$ = maximum electrical power output of the FCS as defined in accordance with subpoint (a) above [kW]

$P_{norm,i}$ = normalized electrical power output of the FCS for all values i as defined in accordance with subpoint (c) above [-]';

(23) in Appendix 12 the following points are added:

'5. Fuel cell systems

5.1 Every FCS shall be manufactured to conform to the approved type with regard to the description as given in the certificate and its annexes. The conformity of the certified CO_2 emissions and fuel consumption related properties procedures shall comply with those set out in Article 31 of Regulation (EU) 2018/858.

5.2 Conformity of the certified CO_2 emissions and fuel consumption related properties shall be checked on the basis of the description in the certificates and information packages annexed thereto as set out in Appendix 7.

5.3 Conformity of the certified CO_2 emissions and fuel consumption related properties shall be assessed in accordance with the specific conditions laid down in point 5.

5.4 The component manufacturer shall test annually the number of units indicated in table 4 based on the total annual production number of fuel cell systems produced by the component manufacturer. For the purpose of establishing the annual production numbers, only fuel cell systems which fall under the requirements of this Regulation and for which no standard values were used shall be considered.

Table 4

Sample size conformity testing

Total annual production of fuel cell systems	Annual number of tests
0 – 3 000	1 test every 3 years*
3 001 – 6 000	1 test every 2 years*
6 001 – 12 000	1
12 001 – 30 000	2
30 001 – 60 000	3
60 001 – 90 000	4
90 001 – 120 000	5
120 001 – 150 000	6
> 150 000	7

* The CoP test shall be performed in the first year.

5.5 The approval authority shall identify together with the component manufacturer the type(s) of fuel cell systems to be tested for the conformity of the certified CO_2 emissions and fuel consumption related properties. The approval authority shall ensure that the selected type(s) of fuel cell systems is manufactured to the same standards as for serial production.

5.6 If the result of a test performed in accordance with point 5.7 does not fulfill the pass criteria set out in point 5.7.4., three additional units from the same type shall be tested. If any of them fails, Article 23 shall apply.

5.7 Conformity of production of testing of fuel cell systems

5.7.1 Boundaries conditions

All boundary conditions laid down in this Annex for the certification testing shall apply unless stated otherwise in this paragraph.

The measurement equipment specifications defined in accordance with point 3.1 do not need to be fulfilled for CoP testing.

The CoP testing may be conducted with regular market fuel. However, at the manufacturer's request, the reference fuel set out in point 7.1.1 may be used.

5.7.2 Testrun

The test procedure shall be performed in accordance with point 7.3.4 following all principles set out therein but with a reduced number of OPs to be measured. The manufacturer may as an alternative option select to measure the complete set of OP from the original component certification following the exact same provisions and boundary conditions as applied during the original component certification and documented in the information document set out in Appendix 7.

The target OPs to be measured shall be defined by the normalized set power, $P@OPxx_{norm}$, calculated in accordance with the following equation:

$$P@OPxx_{norm} = \frac{P@OPxx}{P@OPn_{op}}$$

where:

P@OPxx: target electrical FCS power output at a certain OP between lowest and highest with the identifier xx running from 01 to n_{op}

$P@OPn_{op}$: target electrical FCS power output at highest OP

The target OPs to be measured for CoP testing shall be selected out of the target OPs from the original component certification defined in accordance with point 7.3.4.1 and recorded in the information document set out in Appendix 7 during component certification. The target OPs to be selected shall be defined by the normalized set power values in accordance with the following points (a) to (e):

- OP next lower or equal to 0,15

In case there is no OP lower or equal to 0.15 existing, the lowest OP out of the target OPs from the original component certification shall be used.

- OP next higher to 0,15

In case this OP is already selected for CoP under point (a), the next highest OP out of the target OPs from the original component certification shall be used.

- OP closest to 0,4

In case the next lower and next higher OP are exactly equidistant to 0.4, the next lower OP shall be used for CoP testing.

In case this OP is already selected for CoP under point (b), the next highest OP out of the target OPs from the original component certification shall be used.

- OP next lower to 0,7

In case this OP is selected for CoP under point (c), the next highest OP out of the target OPs from the original component certification shall be used.

- OP equal to 1,0

In case this OP is already selected for CoP under point (d), it shall be measured only once.

With the target OPs to be measured for CoP testing, the provisions of point 7.3.4 including all its subpoints shall apply in order to determine the values of $P_{FCS,\ avg}$ and $\dot{m}_{F,\ avg}$. In that context, target OPs to be measured with the normalized set power of 1 shall be considered as OPn_{op} and only measured once whereas all other target OPs shall be measured twice (i.e. in the ascending and descending path).

5.7.3 Post-processing of results

All values of of $P_{FCS,\ avg}$ determined in accordance with point 5.7.2 shall be processed in accordance with point 7.5 of this Annex to derive the values of final effective electrical power output $P^*_{el,FCS,net}$.

Subsequently, the resulting values of $P^*_{el,FCS,net}$ and $\dot{m}_{F,\ avg}$ determined in accordance with point 5.7.2 shall be corrected for uncertainty deviation of CoP measurement equipment in accordance with points (a) to (f):

(a) The difference in measurement equipment uncertainty in percent between component type approval and CoP testing in accordance with this Appendix shall be calculated for the measurement systems used for current, voltage and fuel mass flow.

(b) The difference in uncertainty in percent referred to in subpoint (a) shall be calculated for both, the analyzer reading and the maximum calibration value defined in accordance with point 3.1 of this Annex.

(c) The total difference in uncertainty for electrical power shall be calculated in accordance with the following equation:

$$\Delta u_{P,el,CoP} = \sqrt{\Delta u^2_{U,\max calib} + \Delta u^2_{U,value} + \Delta u^2_{I,\max calib} + \Delta u^2_{I,value}}$$

where:

$\Delta u_{U,\max calib}$	difference in uncertainty for maximum calibration value for voltage measurement [%]
$\Delta u_{U,value}$	difference in uncertainty for analyzer reading for voltage measurement [%]
$\Delta u_{I,\max calib}$	difference in uncertainty for maximum calibration value for current measurement [%]
$\Delta u_{I,value}$	difference in uncertainty for analyzer reading for current measurement [%]

d) The total difference in uncertainty for fuel mass flow shall be calculated in accordance with the following equation:

$$\Delta u_{\dot{m}_{fuel},CoP} = \sqrt{\Delta u^2_{\dot{m}_{fuel},\max calib} + \Delta u^2_{\dot{m}_{fuel},value}}$$

where:

$\Delta u_{\dot{m}_{fuel},\max calib}$	difference in uncertainty for maximum calibration value for fuel mass flow measurement [%]
$\Delta u_{\dot{m}_{fuel},value}$	difference in uncertainty for analyzer reading for fuel mass flow measurement [%]

e) All values of P*el,FCS,net determined in accordance with point 7.5 of this Annex shall be corrected in accordance with the following equation:

$P^*_{el,CoP} = P^*_{el,FCS,net} (1 - \Delta u_{P,el,CoP})$

where:

$\Delta u_{P,el,CoP}$	total difference in uncertainty for electrical power in accordance with subpoint (c)

f) All values of and $\dot{m}_{F,\ avg}$ determined in accordance with point 7.3.4.7 of this Annex shall be corrected in accordance with the following equation:

$\dot{m}_{F,CoP} = \dot{m}_{F,\ avg} (1 + \Delta u_{\dot{m}_{fuel},CoP})$

where:

$\Delta u_{\dot{m}_{fuel},CoP}$	total difference in uncertainty for fuel mass flow in accordance with subpoint (d)

5.7.4 Evaluation of results

For each target OP for CoP testing, the specific fuel consumption, SFC_{CoP}, shall be calculated from the corresponding values of $P^*_{el,CoP}$ and $\dot{m}_{F,CoP}$ determined in accordance with point 5.7.3 by dividing $\dot{m}_{F,CoP}$ by $P^*_{el,CoP}$.

The type approved specific fuel consumption, SFC_{TA}, shall be calculated from the data of the original component certification for $P^*_{el,FCS,net}$ determined in accordance with point 7.5 of this Annex and $\dot{m}_{F,\ avg}$ determined in accordance with point 7.3.4.7 of this Annex for all target OPs from the original component certification corresponding to the ones applied for CoP. The values of SFC_{TA} shall be calculated by dividing of $\dot{m}_{F,\ avg}$ by the corresponding value of $P^*_{el,FCS,net}$ for each target OP.

Subsequently, the absolute relative deviation, ARD, for each target OP for CoP testing shall be calculated in accordance with the following equation:

$$ARD = \frac{|SFC_{CoP} - SFC_{TA}|}{SFC_{TA}}$$

The conformity of the certified CO_2 emissions and fuel consumption related properties test is passed when the average of the ARD determined out of the individual ARD values of each target OP for CoP testing is smaller than 0,05.’;

(24) in Appendix 13, the following points are added:

‘2. Fuel Cell Systems

2.1. General

A family of fuel cell systems (FCS) is characterized by design and performance parameters. Those shall be common to all members within the family. The component or vehicle manufacturer may decide which FCS belong to a family, if the membership criteria listed in this Appendix are fulfilled. The related family shall be approved by the approval authority. The manufacturer shall provide to the approval authority the appropriate information relating to the members of the family.

2.1 Special cases

In some cases, there may be interaction between parameters. That shall be taken into consideration to ensure that FCS with similar characteristics are included within the same family. Those cases shall be identified by the manufacturer and notified to the approval authority. It shall then be considered as a criterion for creating a new family of FCS.

In case of devices or features, which are not listed in point 2.4 of this Appendix and which have a strong influence on the level of performance and/or the electric power generation, the respective devices or features shall be identified by the manufacturer based on good engineering practice, and shall be notified to the approval authority. It shall then be considered as a criterion for creating a new family of FCS.

2.2 Family concept

The family concept defines criteria and parameters enabling the manufacturer to group FCS into families with similar or equal data relevant for fuel / hydrogen consumption.

2.3 Special provisions regarding representativeness

The approval authority may conclude that the performance parameters and the fuel / hydrogen consumption of the family of FCS is best characterized by additional testing. In this case, the manufacturer shall submit the appropriate information to determine the FCS within the family likely to best represent the family. The approval authority may, based on that information, also conclude that the manufacturer is required to create a new family of FCS consisting of less members in order to be more representative.

If members within a family incorporate other features which may be considered to affect the performance parameters and/or the fuel / hydrogen consumption, those features shall also be identified and considered in the selection of the parent.

2.4 Parameters defining a family of FCS

In addition to the parameters listed below, the manufacturer may introduce additional criteria allowing the definition of families of more restricted size. Those parameters are not necessarily parameters that have an influence on the level of performance and/or fuel / hydrogen consumption.

2.4.1 The following criteria shall apply to all members within a family of FCS:

(a) All family members are of the same type of FCS defined in accordance with table 9 of this Annex.

(b) Fuel Cell Stack with a tolerance of ±5 % for weight & size and with a tolerance of ±2 % for the number of cells and cell surface area.

(c) PCS (if applicable) with a tolerance of ±5 %: efficiency.

(d) Air compressor with a tolerance of ±5 %: efficiency.

(e) Humidifier (if applicable): similar layout and dimension.

(f) Pumps (if applicable): similar layout and dimension.

(g) Heat exchangers: similar layout and dimension.

Upon approval from the approval authority, changes to the components set out in points (a) to (h) may occur if sound engineering rationale is provided to prove that the respective change does not negatively affect the performance parameters and/or the fuel consumption.

2.4.2 The following criteria shall apply to all members within a family of FCS:

(a) Electrical plugs: any changes allowed.

(b) Piping: any changes allowed.

(c) Media actuators: any changes allowed.

(d) Housing: any changes allowed.

(e) Sensors: Changes allowed, if the precision of the 'parent' sensor used in certification process is still met.

(f) Minimum number of OP in the declared operating range: All FCS within the same family of FCS shall have a minimum number of 8 operating points, as defined in accordance with point 7.3.4.1, located within their individual declared operating range specified by the manufacturer in accordance with point 7.3.4 of this Annex.

The application of a specific range to the parameters listed in points (a) to (f) is permitted after the approval of the approval authority.

2.5 Choice of the parent

The parent of one family of FCS shall be member with the highest overall effective electric power output.';

(25) in Appendix 14, point 1.4, table 1, the following row is inserted after the row 'B':

'

F	fuel cell system (FCS)

’;

(26) Appendix 15 is amended as follows:

(a) the section ‘Set of input parameters for Electric machine system’ is amended as follows:

(a) table 1 is amended as follows:

(1) in row ‘CertificationMethod’, column ‘Description/Reference’ the text is replaced by the following:

‘Allowed values: ‘Measured’, ‘Standard values’’;

(2) in row ‘DcDcConverterIncluded’, column ‘Description/Reference’ the text is replaced by the following:

‘Set to ‘true’ where a DC/DC converter is part of the electric machine system, in accordance with point 4.1 of this Annex. Where the parameter ‘CertificationMethod’ is ‘Standard values’, the parameter shall always be set to ‘true’’;

(b) table 6 is amended as follows:

(1) in row ‘CoolantTempInlet’, column ‘Description/Reference’ the text is replaced by the following:

‘Determined in accordance with paragraphs 4.1.5.1 and 4.3.6 of this Annex. The input shall be specified as an average value over both voltage levels.’;

(2) in row ‘CoolingPower’, column ‘Description/Reference’ the text is replaced by the following:

‘Determined in accordance with paragraphs 4.1.5.1 and 4.3.6 of this Annex. The input shall be specified as an average value over both voltage levels.’;

(b) the section ‘Set of input parameters for IEPC’ is amended as follows:

(a) in table 1, the following row is added:

‘

DisengagementClutch	PXXX	boolean	[-]	In case the IEPC is equipped with a functionality that actively, under certain operating conditions, allows for mechanically disconnecting all EMs inside the component from the rest of the vehicle’s powertrain towards the wheels, this input shall be set to true. The exact location of the disconnection may also be located further downstream of the EMs output shafts and include some of the gearing parts of the IEPC being disengaged.

’;

(b) in table 2, in row 'MaxOutputShaftTorque', column 'Description/Reference' the text is replaced by the following:

'Optional.
In case of an IEPC design type wheel motor the declared value for the maximum torque at the output shaft of the component shall correspond to the configuration measured in accordance with point 4.1.1.2 of this Annex (i.e. the value declared if two such components were measured shall be twice as high as if only one single component was measured).';

(c) in table 4, the heading is replaced by the following:

'Input parameters 'IEPC/MaxMinTorque' for each operating point, for each voltage level measured and for each forward gear measured (optional gear dependent measurement in accordance with point 4.2.2(c) of this Annex)';

(d) in table 7, in rows 'CollantTempInlet' and 'CoolingPower', column 'Description/Reference' the text is replaced by the following:

'Determined in accordance with points 4.1.5.1 and 4.3.6 of this Annex.
The input shall be specified as an average value over both voltage levels.';

(c) the section 'Set of input parameters for Battery system' is amended as follows:

(a) in table 1, in row 'RatedCapacity', column 'Description/Reference', the following text is inserted:

'Where the parameter 'CertificationMethod' is 'Standard values', those values shall be determined in accordance with Appendix 10, point (1)(b)';

(b) table 4 is amended as follows:

(1) in row 'SOC', column 'Description/Reference', the text is deleted;

(2) in rows 'MaxChargingCurrent' and 'MaxDischargingCurrent', column 'Description/Reference' the following text is added:

'Where the parameter 'CertificationMethod' is 'Standard values', those values shall be determined in accordance with Appendix 10, subpoint (1)(e), and all values shall have a positive pre-sign.';

(d) in the section 'set of input for Capacitor System', table 1 is amended as follows:

(a) in row 'CertificationMethod', column 'Description/Reference', the text is replaced by the following:

'Allowed values: 'Measured', 'Standard values'.';

(b) in row 'InternalResistance', column 'Unit', the following text is inserted:

'[mOhm]';

(e) the following section is added:

'*Set of input parameters for fuel cell system*

Table 1

Input parameters 'Fuel cell system/General'

Parameter name	Parameter ID	Type	Unit	Description/Reference
Manufacturer		token	-	

Model		token	-	
CertificationNumber		token	-	
Date		dateTime	-	Date and time when the component-hash is created
AppVersion		token	-	Manufacturer specific input regarding the tools used for evaluation and handling of measured component data
CertificationMethod		string	-	Allowed values: ‘Measured’, ‘Standard values’
FCSRatedPower		integer	kW	Defined in accordance with Appendix 1, point 4.6., of Annex 6 to UN Regulation No 100

Table 2

Input parameters ‘Fuel cell system/FuelMap’ for each operating point measured

Parameter name	Parameter ID	Type	Unit	Description/Reference
OutputPower		double, 2	kW	Electric power provided by the FCS determined in accordance with point 7.5.3
FuelConsumption		double, 2	g/h	Fuel mass flow determined in accordance with point 7.5.3.

’.